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Cover: American eels, *Anguilla rostrata*, and their many uses are discussed in the article beginning on page 1. Photograph by Lloyd Poissenot, Louisiana Department of Wildlife and Fisheries.

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Eels and Their Utilization

J. PERRY LANE

INTRODUCTION

To the average American, the image of the common eel conjures up a picture of a snake-like creature slithering through brooks and rivers. The mental picture is often accompanied by an inward shudder of revulsion. This unfortunate association of eels with snakes has deprived most Americans from enjoying a fish that has been considered a gourmet delicacy for thousands of years in many parts of the world. Not only that, but the reptilian association of eels is completely erroneous. The American eel, *Anguilla rostrata,* is a true fish with gills and scales.

The eel itself is a fascinating creature and was, and still is to some extent, the object of one of the greatest biological detective studies of all times. Since the time of the ancient Greeks, man has wondered where the eels came from—where they spawned. For hundreds of years, no one had seen an eel with eggs or milt. Did they really originate from horse hairs dropped into streams as was once believed?

As a food, the eel is consumed in many ways; and in parts of Europe and particularly in Japan, demand has so outstripped supply that young eels—or elvers—have brought several hundred dollars a pound. The Netherlands has sent a specially designed ship with live wells to the United States and Canada to collect mature eels and transport them alive to Europe. The lucrative foreign market for eels has promoted the establishment or expansion of eel fisheries in several eastern States, notably, Maine, Massachusetts, New York, New Jersey, Maryland, Virginia, North Carolina, and Florida, with varying amounts from other States. In 1970 from recreational fishing alone, it was estimated (Statistics and Market News Division, 1975a) that over 4 million pounds (1,814 metric tons) of eels were taken from the Atlantic coastal States, while another 1½ million pounds (680 metric tons) were taken commercially in 1972 (Statistics and Market News Division, 1975b). Eels are usually caught with traps, but otter trawls, hand lines, long lines, fyke and hoop nets, floating traps, spears, haul seines, and pound nets have also been used. Most of this gear was used in some form by the early settlers along the eastern coast, particularly in New England.

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With the worldwide interest in eels and the fact that eel fisheries in the United States go back to the time of the Pilgrims, why have eels been shunned by most of the citizens of the United States? Why are they still largely underutilized here, particularly in light of the present shortage of so many of our more established marine food fish? Perhaps part of the reason is that the public is so unfamiliar with eels, except for the vague misconception mentioned earlier. This paper presents some basic information on the eel, its life history, the various methods of catching and preparing them, and some indication of world demand.

DESCRIPTION

Eels are found worldwide and there are a number of different species. In the United States, when the word "eel" is used alone, one can be quite certain that the fish referred to is the so-called common or American eel, *Anguilla rostrata*. Other names used in this country are the yellow eel, silver eel, and freshwater eel. Young eels are called elvers after they acquire pigment and "glass" eels when colorless. The American eel is found along the coast and in freshwater streams and rivers from Greenland to the Gulf of Mexico and as far south as Panama, the West Indies, and rarely to the northern coast of South America.

The taxonomic or biological classification of eels is as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Osteichthyes
Order: Anguilliformes
Family: Anguillidae
Genus: Anguilla

There have been about 17 species found of the *Anguilla* genus. These are identified in Table 1 along with the parts of the world where they normally occur.

Other eels resemble the American eel to varying degrees. The conger or sea eel has the same serpentine body but grows to a larger size. The conger eel has more vertebrae than the American eel, and the dorsal fin begins just behind the pectoral or side fins, whereas the dorsal fin of the American eel originates much farther back. The conger eel does not enter fresh water. Another fish that might be confused with the American eel is the sea lamprey, *Petromyzon marinus*. This species is parasitic and was responsible for nearly wiping out the lake trout population in the Great Lakes. It has almost no jaws but rather an oval-shaped mouth with many

Table 1.—Distribution of species of the genus *Anguilla* (Eales, 1968).

Species	Distribution
A. anguilla	Europe, Iceland, and North Africa
A. australis	Australia, Aukland Island, and New Zealand
A. bengalensis	Indian Ocean
A. bicolor	Indian Ocean to Malayan Islands, Philippines, and New Guinea
A. borneensis	Borneo
A. celebesensis	Indo-Malaya, Philippines, and western New Guinea
A. dieffenbachi	Australia, Aukland Islands, and New Zealand
A. japonica	China and Japan
A. marmorata	Indian Ocean, most oceanic islands north to the Marianas and south to New Guinea, New Caledonia and Society Islands as eastern limit
A. mauritania	Central Pacific
A. megastomata	New Caledonia, Solomon Islands, eastern Polynesia, Fiji, Tonga, Samoa, Marquesas, Tuamotu, and Tahiti
A. mossambica	Indian Ocean
A. nebulora	Indian Ocean
A. obscura	Australia, New Guinea, East Indies, eastern Polynesia, Fiji, Tonga, Samoa, Marquesas, Tuamotu, and Tahiti
A. pacifica	East Pacific
A. reinhardi	Australia and New Caledonia
A. rostrata	North America and Greenland

hooked teeth which it uses to fasten onto other fish, rasp a hole in their side, and draw out blood which seems to be their main food.

The American eel has an elongated serpentine body that tapers to a point at the tail. It is closely related to the European eel but has a lesser number of vertebrae—about 107 as compared with 114. There are a pair of pectoral fins just behind the head with a small gill opening in front of each pectoral fin. The dorsal fin originates far behind the pectorals, back about a quarter to one-third the length of the body. The dorsal fin runs into and is continuous with the caudal and anal fins. The lower jaw at least equals the upper jaw in length and sometimes projects slightly beyond the upper. Both jaws are lined with many needle-like teeth (Bigelow and Schroeder, 1953).

The color of eels varies widely, depending on the stage of maturity and their habitat. Prior to sexual maturity, they are usually a dark muddy brown or olive brown to black above, yellowish along the sides, and light yellow or dirty yellow-white on the belly. It is in this stage that they are referred to as yellow eels and can be found in fresh water, estuaries, or the sea. Their color can change, depending on the type bottom where they are found and changes in illumination. They can alter their skin color within a matter of hours by redistributing pigments. When these eels reach maturity, the yellow gradually changes to a silvery white, and they are known as silver eels.

Female eels grow to a larger size than males. A mature female will vary from 30 to 42 inches (76.2-106.7 cm) in length and weigh from about 2½ to 3½ pounds (1.1-1.6 kg). Females up to 4 feet (1.22 m) and weighing over 16 pounds (7.3 kg) have been reported. The male can mature at 12 inches (30.5 cm) and usually does not go much over 18 inches (45.7 cm) in length. Any eel over 18 inches (45.7 cm) would probably be a female, and any over 24 inches (61 cm) would certainly be a female.

LIFE HISTORY

Historical Background

The eel was prized as a delicacy by the ancient Romans and was widely observed throughout the waterways of Europe. In fact, the origins of the eel have fascinated people since the beginning of European civilization. They noted that the eels never contained roe or milt as did other fish and this gave rise to a variety of strange myths as to their origin. Some thought they developed from horse hairs falling into streams or rivers or from water beetles. Aristotle, in 350 B.C. in "Historia Animalium," gave his views and observations to support his theory of spontaneous generation. He observed that eels had no seminal fluid or eggs and when dissected showed no seminal canal or womb; therefore, no eels are born from mating or from eggs.

The eel goes from fresh water to salt water and not vice versa, as do other fish (apparently the migration from salt water to fresh water of the young glass eels and elvers was not observed). Aristotle further observed that in pools that had been drained, eels could be found "reforming" themselves after a rain. (Actually, the eels were simply buried in the mud and reemerged when the pool again had water.) Finally, he pointed out that eels come from the "entrails of the earth" where there were places with rotting material such as in the sea where seaweed accumulates, in rivers and at the water's edge, for it was there that the heat of the sun develops and produces putrefaction. By "entrails of the earth," Aristotle may have meant that eels were born from worms or larvae. The idea of spontaneous generation was common in Europe for hundreds of years after Aristotle, of course, and thought to be the way maggots arose from rotting flesh.

Pliny, in his "Natural History," had a unique explanation as to the reproductive process of eels. He said, "to reproduce themselves, eels rub their bodies against the rocks; from the shreds of skin thus detached come new ones." Oppian, in the second century in Sicily, had an equally unique explanation. His theory was that eels mate with snakes. The female eel takes the snake's head in her mouth. Following this union, the eel went to sea and the snake to land.

There was no further scientific enlightenment of the origin of eels throughout the Middle Ages. Scholars of that time mainly reflected the views of earlier philosophers such as Aristotle. It was not until the 17th century that Francesco Redi of Tuscany observed that eels leave fresh water around August and go to sea where, he concluded, the female dropped her eggs. Later the young eels, or elvers, returned to fresh water. This was the first time the small elvers were observed entering fresh water and correctly identified as young eels.

Redi was the first person to refute the theory that eels were born alive. Others had found parasites in mature eels and assumed they were young eels waiting to be born. Leeuwenhoek in 1692 had described the eel's bladder as the womb and the parasitic worms found there as young eels. Others, including Linnaeus in the 1700's, made this same mistake. It was not until 1777 that Mondini in Italy discovered an ovary in an eel, and another hundred years, 1874, passed before an eel testis was discovered. This was done by finally looking at the smaller eels rather than the largest, which were females. In 1896, two Italians proved that the small leptocephali is the larval stage of the eel by watching it change in an aquarium.

American eels, *Anguilla rostrata*. Photographs courtesy of John J. Poluhowich, Research Director, Institute for Anguilliform Research, Department of Biology, University of Bridgeport, Bridgeport, CN 06602.

With this basis of information concerning the European eel at the beginning of the 20th century, it was the remarkable work of a Danish oceanographer, Johannes Schmidt, that finally traced the origin of the spawning area of the European eel and also tentatively identified the spawning grounds of the American eel. His work covered a period of nearly 20 years from 1904 to 1922. He observed that eels from all over Europe had, on the average, the same number of vertebrae, around 114 to 115. This led to the conclusion in 1907 that all eels found in Europe belonged to the same species. This launched Schmidt on his search for the common spawning ground of these eels. This search was to take another 15 years and cover a good portion of the North Atlantic from Greenland along the coast of Europe and North America to the Caribbean and Mediterranean Seas.

He took samples from various depths over a large part of the North Atlantic Ocean and followed the trail of young eels of decreasing size until he identified the Sargasso Sea in the southwest part of the North Atlantic, generally between Puerto Rico and Bermuda, as the common spawning ground of all European eels. During his studies, he also took a relatively few specimens of the larvae of American eels and identified their spawning area as somewhat to the west of the European eel, but still in the general area of the Sargasso Sea. Schmidt defined the European eel's spawning area as being between lat. 22°-30°N and between long. 48°-65°W. The dividing line between the spawning area of American and European eels is considered to be long. 50°W.

Life Cycle

The description of the life cycle which follows applies to both the European eel, *A. anguilla,* and the American eel, except where specific differences are noted. Léon Bertin (1956), from which most of the information on life cycle is drawn, said that "there can hardly in the whole of natural history be a more remarkable example of response to environment, to temperature, to salinity, to light, and to current," than that exhibited by the eel during the course of its life.

The European eel spawns at a depth of about 400 m (437 yards) inside a 17°C (63°F) isotherm. Each species of eel seems to have a definite temperature preference for spawning, and this seems to be the best evidence for the location of the spawning area of the European eel in the Sargasso Sea. The

evidence supporting the actual location of the spawning grounds of the American eel is not as clear cut. The spawning time for the European eel is during the spring, with most spawning occurring in May and June. The American eel spawns over a longer period from February to July (Bertin, 1956). Each female is capable of producing as many as 15-20 million eggs about 1 mm (0.04 inch) in diameter.

No spawning eels have been taken nor have any mature eels been seen after they have spawned. It therefore appears that the adult eels die after spawning so that the Sargasso Sea becomes at the same time the nursery of young eels and the graveyard of adults. After the larvae are hatched, they go through an embryonic phase lasting a few days. During this time, they derive their nourishment from the yolk sac. They next enter the larval stage and gradually rise to the surface. During the larvae stage, the young eels are known as leptocephali. These are transparent and ribbon-like and are said to resemble willow leaves. They have small pointed heads and long teeth. They join drifting plankton on which they feed and travel under the influence of the ocean currents towards continental water. These flat and glassy leptocephali are so unlike mature eels that it is not surprising it took so long to identify them as young eels. In fact, the name leptocephalus means flat head.

One of the major differences between American and European eels is the length of time they remain in the leptocephali stage and the time it takes them to reach the continent. For the small leptocephali that are carried north or south into cold currents from Labrador or into the warm ones from the equator, there is death. Only those that reach the proper currents to carry them toward Europe or North America survive. It takes the European eel from 2½ to 3 years to make the long migration; whereas, the American eels make their journey in about 1 year. During their transatlantic migration, the eel larvae travel on the surface at night and descend into deep water during the day.

The leptocephali of the American eel with a shorter distance to travel reach the freshwater streams of North America by the spring of the year after they were spawned. The European leptocephali take about 2½ to 3 years as was noted above. During this time, the transformation or metamorphosis to young eels or elvers is accomplished. This is probably the most significant difference between the European and American eels; that is, the time spent in migration from the spawning ground to their respective continental waters and the timing of their metamorphosis to coincide with this journey.

Before describing this change in the young eels, it should be pointed out that there has been some question as to the accuracy of Schmidt's assumption that the westerly part of the Saragasso Sea is the spawning ground of the American eel as well as the European eel. Vladykov and March (1975), raise several points concerning the information and conclusions drawn from Schmidt's work. First, no female American eels have been taken in as advanced stages of sexual maturity, as have been reported for European eels. No spawning eels or eggs have been taken (Schmidt's evidence is based on the capture of young larvae). Schmidt followed the trail of the European eel by capturing larvae of decreasing size. Since he was not studying the American eel, it may be that the collection stations used were not in the proper locations to take American eels. The same applies to the water depth sampled. Each eel species seems to have its own depth and temperature preference, and again it may be that in sampling depths preferred by the European larvae, the American ones were missed. The actual spawning season is still only generally defined, particularly for the American eel.

There is limited information on the exact duration of the larval stage of the American eel (reported as 1 year as opposed to 2½ to 3 years for the European eel). If the western Sargasso Sea is the spawning ground for the American eel, the question is raised as to the mechanism by which the larvae successfully cross the complex currents of the Gulf Stream. Finally, there is the question as to how the American eels reach their southernmost limits of Trinidad and the Guianas which are about 13° of latitude south of the reported Sargasso Sea spawning area. The currents would take the young larvae north, not south, and seem to make a southern migration impossible. With these questions still unresolved, the best that can be said at this time is that the true spawning area of the American eel has not been definitely established.

Metamorphosis of Leptocephali to Elvers

Regardless of where they were spawned, by the time they reach the continental waters the change to elvers is accomplished. This change consists of a change in shape from leaf-like to the beginning of a cylindrical shape. Both the length and weight of the young eel decrease as it goes from leptocephali to glass eel, which is an unpigmented elver. The loss in weight is due mainly to loss of water from the body. The intestines become shorter and the long larval teeth fall out and are replaced by definitive teeth. These elvers go through a short inactive phase of metamorphosis during which these changes take place, and this is partly responsible for the loss in weight as well as the decrease in length. The young elvers after the inactive phase are vigorous and agile as they approach the coast.

About 1 year after hatching, around December and January, the American eels reach the coast and undergo the changes described above. The elvers are about 1½-2¾ inches (6.4-7.0 cm) long. The European eels reach the Spanish coast in October but do not complete their journey to the Baltic Sea until the following May.

As the glass eels approach brackish water, metamorphosis is completed and pigmentation begins. This requires a variable amount of time, and in many streams during the spring, migration of glass eels can be observed before pigmentation occurs. The upstream run to fresh water begins as early as February in North Carolina and in May and June in Canada. After pigmentation is complete, the elvers gain weight and increase in length. The change from elver to young eel is thus completed.

Only a portion of the young eels or elvers enter fresh water. The rest stay in estuarine areas such as tidal marshes and harbors or remain in coastal areas of the sea. While the evidence is not conclusive, it appears that the female eels migrate into fresh water while the males generally stay in the estuarine or coastal area.

Upstream Migration

The migration of the young elvers into fresh water lasts anywhere from a few days to a month or more. The elvers move upstream at night, and during the time of their spring run, may be seen by the thousands by use of a light on the water surface at night. They are very strongly oriented toward swimming against the current, and this fact has been utilized in trapping the elvers—opening of trap downstream, blind end upstream. During the daylight hours, the elvers will seek cover by burrowing into the mud or hiding under rocks.

As American glass eels enter fresh water, they average about 2½ inches (62 mm) in length and number about 2,500 per pound (5,500 per kg).

During the upstream migration, the elvers tend to follow along the banks of rivers and streams in shallow water. Their persistence during migration upstream is remarkable. They will cling to damp rocks and will even climb up concrete dams as long as the surface is moist. Should they reach a portion of the waterway where the current is too strong, they may leave the stream and go around it through the damp grass and over wet rocks along the edges until the swift water is passed and then return to the stream. When an obstruction is encountered, such as a waterfall or dam, during the peak of the migration, large numbers of elvers may collect while waiting their turn to climb the rocks or dam and thus resume their journey on the other side.

The more barriers between an inland body of water and the sea, the less likelihood there is of the elvers reaching it. It is possible for them to gain entrance to bodies of water with no visible connection to the sea. They may do this by using underground channels or even traveling overland through dew-laden grass if the distance is not too great. They will also use underground water pipes if an access can be found and have been known to fill the pipes in such numbers that they block them completely.

Eels rely primarily on olfactory stimuli to direct them to fresh water, and there is no evidence to indicate that the young elvers return to the same waterways which their parents inhabited. Indeed, since chance in the form of ocean currents and winds plays such a large part during their migration as larvae in the sea, the odds against any given elver returning to the exact same body of water occupied by his parents would seem astronomical.

The young eels populate warm shallow lakes in large numbers and tend to avoid extremely cold streams. After reaching their destination, they will remain in fresh water from 5 to 18 years, although this time is quite variable and eels as old as 20 years have been taken from fresh water.

Yellow Eel Stage

It is in the freshwater ponds, lakes, and streams that the eels change to the yellow state and assume the black-yellowish condition described earlier. This is the growth stage. The male European eel will stay in this stage for 8-10 years, while the females may remain in fresh water for 10-18 years. The American eel is believed to stay in fresh water a shorter time, generally from 5 to 10 years.

During their stay in fresh water, eels grow slowly. They are generally omnivorous during this period and will eat a wide variety of organisms such as insects, fish, crustaceans, snails, worms, and even one another on occasion. They rely on an acute sense of smell to locate and catch food. Eels definitely prefer fresh food and will not eat rotten or decaying material. They are active and feeding on warm dark nights. Feeding activity is largely related to light intensity—the less light, the more active. During daylight hours, eels generally hide in deep holes or bury themselves in mud, although occasionally they will be active during daylight hours. In cold weather, they become sluggish and inactive and will bury themselves in the mud. Should a body of water dry up, eels are capable of staying alive in the moist mud and will reappear after a rain has replenished the water supply.

At about 6 years of age, they develop tiny scales. These are definite and well-defined scales but are so small that they may escape detection.

Since eels will eat almost anything, they do have some effect on other fish populations. Larger eels have been reported to eat young salmon eggs. On the other hand, trout have been known to eat young eels. The eel is extremely hardy and can live out of water longer than most other fish because of the protection of the gills from drying out and the fact that it has a lower metabolic rate than a species such as the brown trout. Because the eel can thrive in such a variety of freshwater conditions, it is often thought to have a superior survival potential than most other fresh water fish, although in general this does not seem to be the case. Where there appears to be a struggle for survival between eels and trout or salmon, it is mainly due to the competition for a common food supply rather than predation by one species on another.

There is little information available on the habits of those yellow eels that remain in marine waters and estuaries. It is believed that at least some of them move into the warmer fresh waters and bury themselves in the mud during winter as do their freshwater relatives. It is also thought that when yellow eels have been reported migrating downstream in the spring that it may simply be some of these marine eels going back to saltwater.

In general, the more rapid the sexual development of an eel, the less is the body growth. Males develop faster than females and as a results are considerably smaller. There is a record (Bertin, 1956) of a female eel being kept in an aquarium for 38½ years and reaching a length of 55 inches (140 cm), and of another that was kept to an age of 25 years and grew to 43 inches (110 cm) and a weight of 5½ pounds (2,500 g). The increase in size and weight attained during the growth phase (yellow eel)

depends more on the availability of the food supply than anything else. Temperature is also a factor since cold weather inhibits activity and cuts down feeding. A colder environment will also slow sexual development so that in the long run cold-water eels may grow to a larger size than their warmwater counterparts, although it takes them longer to do so. Eels of the same species, age, and sex can vary greatly in size, depending on environmental factors, and the weight of one eel may be as much as five times that of another of the same age.

Sexual Development

The sexual development of the eel, like so many other of its traits, is rather unique. About 90 percent of the European eels (and it is assumed the American eels also) pass successively through a neutral (no sex differentiation) phase, a period of precocious feminization (when they will begin to develop female traits), and a phase of juvenile hermpahroditism (both female and male characteristics) before becoming definitely male or female. In the young eel, the gonads are undifferentiated; this is the neutral phase. During the yellow eel phase, usually between 5 and 8 years of age, they will develop both male and female characteristics and yet be incapable of reproduction. This is the hermaphroditic stage and is generally a temporary condition, although some eels never leave this stage of development. Next, when the eel is nearing maturity and ready to leave the yellow eel stage for that of the silver (or bronze) stage, final differentiation into male or female takes place. This is usually not completed until the eels are well into their final marine migration towards the spawning grounds. Those that will develop into males are more precocious and will become silver eels, sexually mature, around 8 years of age, where the females will not reach maturity until 10 to 18 years (somewhat younger for American eels).

It is interesting to note that while most eels pass through these various phases of sexual development, about 10 percent are females from the very beginning. The final sexual determination of the other 90 percent is due to various external conditions as yet not clearly understood, but this is not the case for the 10 percent that are females from the beginning. Apparently, the environment plays no part in determining their sex. Final sexual maturity is completed by the time the spawning grounds are reached or shortly thereafter.

Silver Eel Stage

Each fall some of the larger and older yellow eels undergo transformation into silver eels. This change has not been well documented for the American eel, and most of the studies have been on European eels. Again, it is assumed that the following information applies to both species unless otherwise noted.

Several changes take place during this transformation. First, and most noticeable, is the change in coloration. The color of the European eel goes from yellowish to silver, while the American eel has been described as being more "bronze." This change in coloration from yellow to silver has been described by Bertin (1956) as "acquiring the specific nuptial dress or, a more appropriate term, migration livery" as it prepares for its long journey to the spawning grounds.

In addition to changes in coloration, this metamorphosis is marked by several other changes. The digestive tract degenerates and the eel ceases to feed. (For this reason, during the full downstream migration the silver eels are impervious to the temptation of any type of bait.) Other changes include an increase in the production and a thickening of the mucus, which is plentiful and copious during the yellow eel stage but thinner in nature, a thickening of the skin, and an accumulation of fat. There is an alteration in body flexibility and a change in locomotive behavior and the eyes are greatly enlarged. Sexual development is accompanied by an increase in endocrine activity. The number of chloride cells in gills increases and there are changes in osmoregulatory capacity to assist in adapting to a saltwater environment again (D'Ancona, 1960). Similar, although perhaps not exactly parallel, changes occur in the American eel, although the eyes do not enlarge as much (at least American eels with such extreme enlargement have not been taken, although there is the possibility that further enlargement takes place during the marine migration).

The passage of the silver eels from fresh water to salt water takes place between late August and mid-November for American eels, while the European eels generally run from October to December. The exodus of eels from European waters will run into millions and possibly billions of individuals. The silver eels will show as much determination in reaching the sea as the young elvers did in reaching their freshwater home.

The downstream movement is set in motion by changes in the environment. An increase in water level and a dark night seem to be favorable conditions for beginning the migration. Large runs of American eels often occur on warm, dark, stormy nights in late summer or fall. Light intensity is a critical factor, and this fact has been capitalized in catching eels during the fall run. Lights are placed in strategic positions to block the passage of the eels and to divert them into waiting traps or nets. On the Mediterranean coast, up to 10 tons of eels have been caught in one night during this fall run.

One of the remarkable adaptions that takes place during this final metamorphosis is the eel's ability to go directly from fresh water to salt water. This property of euryhalinity involves a series of complicated physiological changes that enable eels to resist changes in salinity. Part of this resistance is due to the thick viscous mucus or slime that coats the eel and forms a barrier to osmotic exchange between the eel's body and its environment.

A factor that helps sustain the eel during its long migration at sea without eating is a toxic property (ichthyotoxin) of the eel's blood. This toxin is potent enough to cause infections in humans who might come in contact with it through an open cut or break in their skin. The blood serum has a neurotoxin that can destroy red blood cells. In some way the toxin helps the eels to

resist starvation, asphyxiation, and wounds. To quote Bertin (1956) again in describing the eel, "Its exceptional endurance, its untiring energy, and its tenacity of life which manifests themselves particularly on the long migrations would be sustained by the ichthyotoxin impregnating its whole organism."

Of the long spawning migration of both the European and American eels, little is known. Presumably, it takes them 2 or 3 months to reach the spawning grounds from North America and a longer period of time from Europe. What depths they swim at or what factors guide them to their final destination is unknown, but return they do. Here in the depths they mate, spawn, and presumably undergo disintegration of some type and die.

Summary of Life Cycle

The life cycle of the eel can be summarized as follows: Eels have several life phases and two distinct metamorphoses. First is the embryonic phase, lasting a few days, when they are nourished by the yolk sac. Second, the marine larval phase (leptocephalus) or dispersal phase, lasts 1-3 years, depending on the species. During this phase, they are carried by the ocean currents towards North America-Europe and feed on microplankton. Third is the inactive phase or first metamorphosis from leptocephalus into elver. This lasts a few months. Fourth is the growth phase or yellow eel phase which lasts several years in fresh water, estuaries, or coastal salt water. During this phase, the eels are omnivorous. Fifth is the second metamorphosis from yellow eel to silver eel. This is also an inactive growth phase and lasts about 1 year. During this time sexual maturity takes place. Sixth is the adult marine phase or phase of reproduction. This is the time of the marine migration to the spawning grounds, mating, reproduction, and presumably death.

FISHERIES

Of the seventeen or so species of eels of the genus *Anguilla* found in the world, five of them occur in the temperate zone. It is these temperate zone eels

Table 2.—World catch of eels, *Anguilla* sp. (Food and Agriculture Organization of the United Nations, 1974).

		Catch (1,000 t)								
Species	Country	1965	1966	1967	1968	1969	1970	1971	1972	1973
European eel	Morocco	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0
A. anguilla	Tunisia	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8
	Turkey	0.2	0.2	0.1	0.3	0.3	0.4	0.5	0.5	0.5
	Denmark	3.2	3.7	3.5	4.3	3.7	3.4	3.2	3.3	3.6
	German Dem. Rep.	1.1	1.2	1.3	1.2	1.0	1.1	0.8	0.9	0.9
	Italy	3.2	3.1	3.1	3.2	3.4	3.2	3.3	3.2	3.2
	Netherlands	2.6	2.8	3.1	2.7	2.8	1.5	1.2	1.1	1.1
	Poland	0.9	1.0	1.1	1.1	1.1	1.0	0.9	0.9	0.8
	Portugal	—[1]	—	—	—	—	—	—	0.1	0
	Spain	1.7	1.7	1.6	1.5	1.5	1.2	1.2	1.5	1.2
	France	1.7	1.3	2.0	2.7	1.9	4.2	4.9	2.6	3.9
	German Fed. Rep.	0.4	0.5	0.6	0.6	0.5	0.5	0.5	0.4	0.4
	Ireland	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
	Norway	0.5	0.5	0.5	0.6	0.5	0.4	0.4	0.4	0.4
	Sweden	1.8	2.0	1.6	1.8	1.7	1.2	1.4	1.2	1.1
	U.K. N. Ireland	0.8	1.0	0.6	0.6	0.6	0.8	0.8	0.7	0.8
	U.S.S.R.	0.3	0.4	0.4	0.4	0.5	0.6	0.6	0.6	1.1
Total *A. anguilla*		19.1	19.9	20.0	21.5	20.0	20.1	20.2	17.9	19.9
American eel	Canada	0.8	0.7	0.8	0.9	1.1	1.1	1.2	1.1	0.7
A. rostrata	U.S.A.	0.8	0.6	0.7	0.8	0.9	1.0	1.1	0.9	1.1
Total *A. rostrata*		1.6	1.3	1.5	1.7	2.0	2.1	2.3	2.0	1.8
Japanese eel	Japan	18.8	19.8	22.8	26.7	26.5	19.4	16.8	16.5	17.3
A. japonica	Korea Rep.	—	—	—	0.3	0.4	0.1	0.2	0.1	0.1
	Other	0.2	0.2	0.3	0.6	1.6	2.0	3.9	—	—
Total *A. japonica*		19.0	20.0	23.1	27.6	28.5	21.5	20.9	16.6	17.4
Australian eel	Australia	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0
A. australis	New Zealand	0	0.1	0.1	0.3	0.4	0.9	1.5	2.1	1.3
Total *A. australis*		0.1	0.2	0.2	0.5	0.6	1.0	1.7	2.3	1.3
Total, all *Anguilla*		39.8	41.4	44.8	51.3	51.1	44.7	45.1	38.8	40.4

[1]Dash indicates no data reported.

that constitute the vast majority of the commercial catch in the world. The European eel, *A. anguilla*, is caught by some 17 European countries plus Morocco and Tunisia in Africa, Syrian Arab Republic and Turkey in Asia, and the U.S.S.R. The American eel, *A. rostrata*, is taken on the east coast of Canada, the United States, and Mexico. The Japanese eel, *A. japonica*, is taken principally by Japan with lesser amounts by Korea and other Asian counties; the Australian eel, *A. australis*, is taken commercially by Australia and New Zealand. Another species, *A. dieffenbachii*, is also caught in the latter two countries but not reported separately in FAO (Food and Agriculture Organization, United Nations) statistics. Table 2 gives information on world catch of eels in thousands of metric tons (t) as reported to FAO for the years 1965 to 1973.

The world commercial catch is composed primarily of the European and Japanese eels. In 1970, for example, European eels accounted for 44,220,000 pounds (20,100 t) and Japanese eels for 47,300,000 pounds (21,500 t) out of a total reported world catch of 98,340,000 pounds (44,700 t). The U.S. catch that year, as reported to FAO, was only 1,000 t (2,200,000 pounds). The Japanese production of eels is largely from eel culture rather than harvesting of wild eels; and in 1970, of 19,400 t reported, 16,700 t were from cultured eels and 2,700 t from inland catch.

It can be seen from Table 2 that Japan is far and away the leading eel producing country in the world. European countries with significant production are Denmark, German Democratic Republic, Italy, Netherlands, Poland, Spain, France, and Sweden. In the past, England had an active eel fishery. The migration of elvers in the spring brought huge numbers of the young eels up the rivers. These swarms were called "eel fares" and were actively pursued. Yet, since 1963 no landings of eels have been reported from any part of the United Kingdom except Northern Ireland. European eel fisheries, in general, are feeling the impact of increased population and urbanization. Problems with pollution, waterways blocked by

Table 3.—Eel production and value in the United States by state, 1972.

State	1,000 lb	Metric tons	1,000 dollars
Maine	70	31.7	25
New Hampshire	5	2.3	1
Massachusetts	55	24.9	22
Rhode Island	22	10.0	8
Connecticut	48	21.8	14
New York	149	67.1	65
New Jersey	262	118.8	58
Delaware	45	20.4	11
Maryland	230	104.3	33
Virginia	492	223.2	145
North Carolina	77	34.5	12
South Carolina	42	19.1	4
Georgia	10	4.5	2
Florida	61	27.2	9
Total	1,568	709.8	409

dams and other obstructions, all inhibit the traditional freshwater fisheries for eels; and this, in turn, has promoted increased interest in eel culture. In fact, the harvest of eels has not increased much in the last 30 years.

Japan has had a long-standing eel fishery. This was the first country to turn to eel culture to supplement their harvest of wild eels. In recent years, the proportion of wild eels to cultured eels has steadily declined. There is an active fishery for elvers which are used to stock the ponds for cultured eels. The domestic catch of elvers cannot keep up with the demand and has prompted the Japanese to actively seek American and European elvers, although these are not considered as desirable as the Japanese eels.

In Australia and New Zealand, nearly all eels caught belong to the species *A. australis*. These eels were a traditional food for the native New Zealand Maoris, but it has only been in recent years, the late 1960's and early 1970's, that eels were fished commercially to any extent. They are now becoming an important export commodity. It is estimated that New Zealand has a potential sustainable harvest of 10-20 million pounds (4,535 to 9,070 t) of eels per year (Skrzynski, 1974), although the reported catch in 1972 was only around 4.5 million pounds (2,041 t). In Australia, silver eels are preferred. The fishery is increasing but still limited with about 0.5 million pounds (227 t) reported in 1972 and none reported in 1973.

In Canada, eels are found in most of the coastal rivers in Newfoundland, Nova Scotia, Prince Edward Island, and New Brunswick. Eels have entered the St. Lawrence River and reached Lakes Ontario and Erie. In fact, the best Canadian commercial fisheries are along the St. Lawrence estuary. The northeast shore of New Brunswick and the southwest coast of Nova Scotia also support small commercial eel fisheries. Canadian catches have run around 2 million pounds (907 t) per year the last 10 years and reached a high of 2.7 million pounds (1,224 t) in 1933. Most of the Canadian catch comes from Quebec where the fishing is primarily for silver eels (Eales, 1968).

In the United States, eel fisheries on a limited scale have existed since colonial times. In 1621, Edward Winslow of Plymouth wrote, "In September we can take a hogshead of eels in a night, with small labor, and can dig them out of their beds all winter." In fact, one of the rivers near Plymouth was called Eel River; and in 1833, the eel fishery in this same river was described: "It is appropriately called Eel River from the abundance of eels which it yields to the support of the industrious poor. Perhaps it will not be extravagant to say that about 150 barrels are annually taken there," (Goode, 1887).

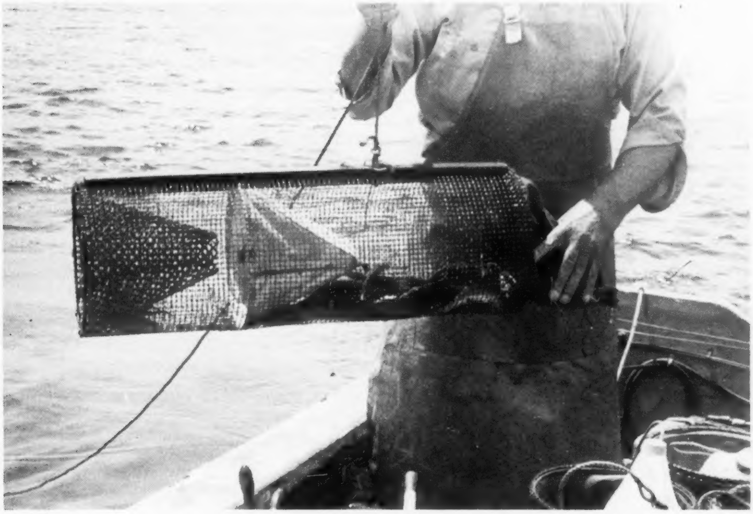
There were eels taken along the coasts of Cape Cod and Maine and Massachusetts in the 1600's and 1700's. In 1887, several eel fisheries were reported from Maine, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and North Carolina. In 1879, small catches from Gloucester, Newburyport, Salem, and Marblehead, all in Massachusetts, brought 5 cents/pound, while Boston with landings over a quarter of a million pounds (454 t) for that year seemed to be the center of the New England eel trade. New Jersey in the Cape May area also had a significant eel fishery in 1879. Most of these eels were speared in the winter or taken in the sea in summer and consumed locally or sent to New York or Philadelphia. The price paid to the fishermen was 4 to 5 cents/pound.

Over the last 40 years, the U.S. eel catch has remained fairly constant, ranging from a low of around 660,000 pounds (299 t) in 1962 to a high of about 2½ million pounds (1,134 t) in 1971 with the catch most years between 1 and 2 million pounds (454 and 907 t). Eel production and value sales for the year 1972 are given in Table 3.

The data in Table 3 show that in 1972 Virginia was the leading state in eel production with nearly half a million pounds (227 t) followed by New Jersey, Maryland, New York, North Carolina, and Maine, in that order. However, this situation may be changing rapidly. In Maryland, one of the primary uses of eels has been as salted bait for use in catching crabs on trot lines. Increased use of crab pots, which do not use salt eels for bait, has reduced landings in that state; and in 1973, only 157,000 pounds (71.2 t) were landed. North Carolina, on the other hand, has been rapidly expanding her eel fishery for export as a food product, and it is estimated that in 1973 the catch may have jumped to over half a million pounds (227 t) (Angel and Jones, 1974). Maine has been attempting to establish an elver fishery, with mixed results to date. Elvers will not increase poundage landed significantly since a pound (0.45 kg) may contain from 1,000 to over 5,000 individuals but can appreciably increase the value because of the high price per pound.

Several coastal states are taking an active interest in exploiting the increased demand for eels in Europe and Japan. It may be that the U.S. fisheries for this species will increase in future years as our resource seems to be greatly underutilized. However, based on the longer experience of both Europe and Japan, it seems unlikely that production of wild eels will ever rise above a few million pounds per year. Even an increase in landings to say 5 million pounds (2,268 t) annually would more than double present U.S. supply and at an average price of 30 to 40 cents/pound (0.45 kg) to the fishermen be worth $1.5 to 2.0 million a year. While little information is available as to the stocks or the maximum sustainable yield that can be achieved in the United States with eels, 5,610,000 pounds (2,544 t) a year would appear to be attainable. Due to the increasing pres-

Dip netting elvers (left), just one of several ways in which elvers are captured. At right is a catch of approximately 2 kg of elvers. Photos courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.



The round or cylindrical eel pot (left) is commonly used by North Carolina eel fishermen. At right is the newer square eel pot which may replace the cylindrical one. Photos courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

sure on our waterways from population, power sources, and obstructions, it is likely that increased interest on the part of the United States in eel production will result in more attention being given to eel culture as was the case in Japan and is beginning in Europe.

METHODS OF CATCHING EELS

There are a number of means of capturing eels in use around the world. Most of these methods are essentialy the same as have been in use for hundreds of years. The method chosen depends on the type of eel, the stage of development one wishes to capture, and makes use of the biological habits of the eel during these different stages.

Eels tend to congregate at three different times. The first time is the spring run of elvers going upstream. These young eels are strongly oriented toward going upstream, and this fact can be capitalized on in capturing them. The yellow eels tend to congregate during their winter inactive phase in deep holes with muddy bottoms. Yellow eels may also be found in limited numbers making a spring run from fresh water to salt water. These are primarily male eels returning to their estuaries or marine environment and are therefore generally smaller than female yellow eels remaining in fresh water. In the late summer or fall, there is a second migration of silver eels from fresh water to the sea. Since these eels cannot feed, the method of catch is based on trapping them in their journey down the waterways to the sea. Yellow eels can be taken at other times when they are not

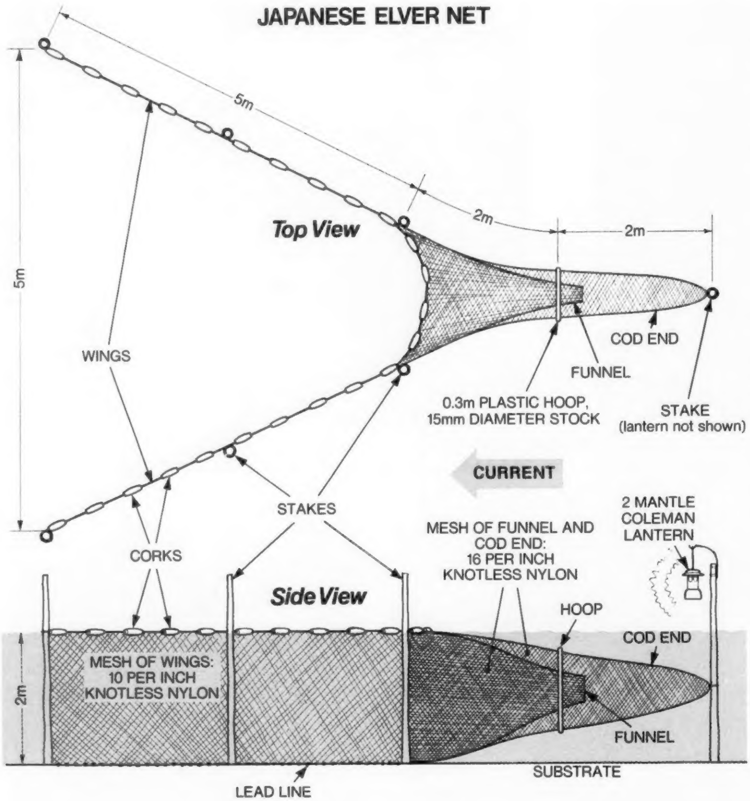


Figure 1.—Japanese elver net, from Topp and Raulerson, 1973.

closely congregated but are actively feeding, by using bait. We will consider ways of catching elvers.

Elvers are caught for food to a very limited extent. Young elvers or glass eels are fleshy, white when cooked, and reported to be quite tasty. Once they become pigmented elvers, they lose flesh, become tough, and are dark when cooked. In England, glass eels were used to make an elver cheese. In Spain, they were consumed in elver omelettes and as pates (Bertin, 1956). They may also be canned in oil. Most elvers are caught, however, for use in stocking inland lakes or for use in more controlled eel culture.

Fine mesh purse seines have been used in France from boats near the shore to capture the young elvers as they approach the coast. The purse seine is a long net of uniform width with a series of floats on the top and weights on the bottom so that it will float upright in the water. The net is fastened at one end to a boat or the shore and the other end moved by another boat (or by hand in very shallow water) to encircle a school of fish. Once the encirclement is completed, a line running through a series of rings along the bottom of the net is pulled tight to close or "purse" the net. The net is gathered in, forcing the elvers into a small pocket from whence they are lifted out with a small dip net.

Another method of catching elvers is used in streams or rivers and involves trapping them as they make their way upstream. So strong is the instinct to travel upstream that a V-shaped trap with the small end upstream leading to another enclosure will catch elvers. As long as the flow of water is not reversed (as from tidal action), the elvers will continue to head upstream and not turn around and escape through the downstream opening. The trap is placed in a constricted part of the waterway or has wings or leaders of fine mesh netting of wire set to direct the elvers into the trap.

A trap of this type can be made using any fine mesh screen, although nylon is preferred to metal since it is not susceptible to rusting. A good description of an elver trap is given by Sheldon (1974). The Japanese use a mesh net and an upstream light source to catch elvers (Fig. 1). Lights can be used to attract glass eels, but once they become pigmented the elvers will avoid light.

Elvers may also be taken from areas below obstructions such as waterfalls or dams with dip nets. In small shallow pockets of water, an aquarium-type dip net is better than the larger variety (because of the size of the water pocket). It must be stressed that while many modifications of these nets and traps will work if positioned in the right spot, they are useless unless one knows when the elver run will occur in a given area and which streams, rivers, etc., are most frequented.

Yellow Eels

Since yellow eels are actively feeding except in cold weather, they can be attracted by bait. A large variety of baited traps have been used successfully to catch them. Goode (1887) described a trap used in colonial times: "When ascending the rivers and small streams in the fall or leaving them in the early spring, large quantities are taken by obstructing the flow of water and placing in the center of the stream a strong barrel pierced with auger holes into which the eels creep, but out of which, curiously enough, they seem unwilling to stir. The barrels have been so filled at times as to suffocate a large part of the catch before morning." It is interesting to note the reverse run of eels mentioned here—that is, descending in the fall and ascending in the spring. Either this was a large run of male eels or Goode has made an error. He later describes a box trap used in New Bedford, Mass., in the 1800's as being 4 feet long and 10 inches wide

with slatted sides and 4-inch square holes in each end with 2 small wooden slats that opened when the eel went in but snapped shut behind him. These traps were weighted with stones and used clams for bait.

All baited traps or pots, of which there are a wide variety, operate on the same principle. The eels are attracted by the smell of the bait into the large end of a funnel-like opening. The narrow end of the funnel leads to a small opening into a container and quite often the process is repeated into a second compartment. Sometimes the bait will be exposed to the eels after they enter the trap and in other cases only the odor will reach them as the bait itself is protected by a bag or perforated container of some type.

Eel pots come in all shapes and sizes. A pot or trap made of willow branches was used by the American Indians and the early colonists and is still in use to some extent in parts of the United Kingdom and Canada. This trap resembled a large basket with the funnel-like opening forming a double lining into the basket. The smaller end of the basket was tied off with twine while the trap was fishing and released to remove the captured eels.

From willow branches, the construction of eel pots evolved more to those with wooden frames and netting. Traps were also made of wood slats and were either round or rectangular in shape (Fig. 2). Today, most eel pots closely resemble the eel pot in the middle of Figure 2, except that they are made of galvanized wire rather than twine netting. The cones or funnels may be of wire, nylon cloth, nylon twine, or even light gauge sheet metal. The bait is placed in the last section so the eel must pass through both funnels before reaching it, thus making it doubly difficult to find the two small openings that would lead to escape. Detailed information on the construction of both a round and a square pot made of galvanized wire or vinyl coated wire is given by Berg et al. (1975).

Other baited traps have been made from such simple things as a section of pipe to which a burlap sack is tied. The sack will contain the bait and perhaps some hay or straw to make it more difficult for the eel to find his way back out of the pipe. Modified lobster and crab traps have been used. The entrances are changed to a funnel arrangement; and, of course, the space between the wood slats or the size of the mesh in the wire must be small enough to prevent the eels from escaping. The traps made from wooden slats are also shown in Figure 2.

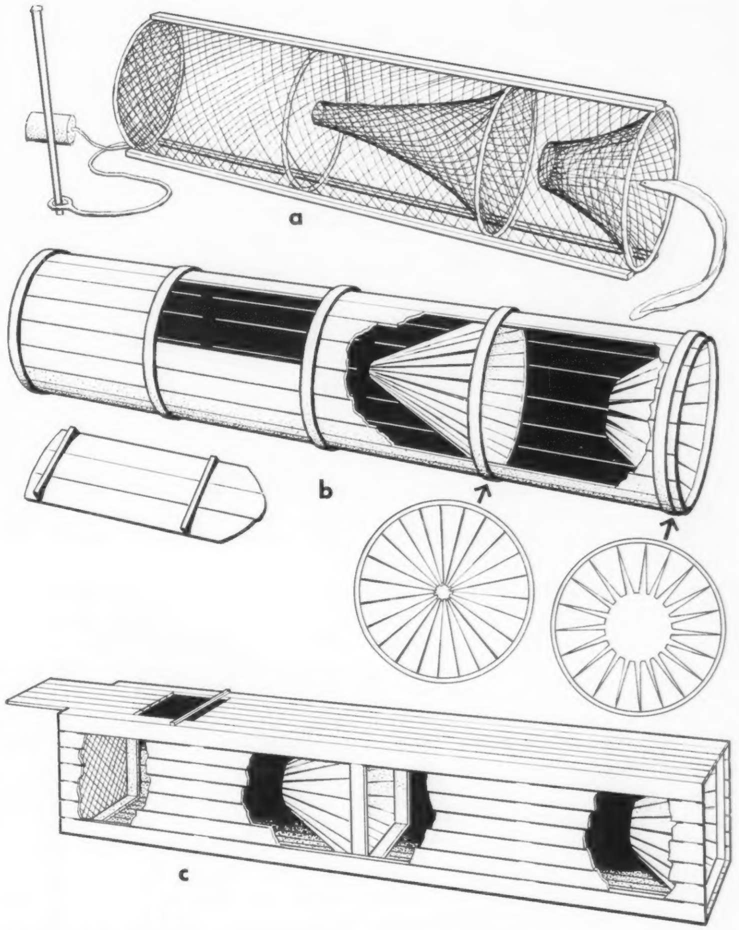


Figure 2.—Eel pot (a), slat trap (b), and basket trap (c) (after Dumont and Sundstrom, 1961).

The bait used in these traps must be fresh and can be placed loose or fastened in the inner chamber (usually called a "parlor") or can be cut or chopped fine and placed in a bag. Most any form of marine life can be used as bait, depending on what is available locally. Herring is often used, but menhaden, alewives, mackerel, squid, crabs, clams, mussels, and even fish waste ("gurry") from a filleting operation could also be used as long as they are fresh. Frozen bait can be used either slacked out (thawed) or frozen as it will quickly thaw in the water. The pots should be tended daily, and the bait changed. Pots and traps are usually set in rivers or streams with the opening facing downstream[1] or in estuarine areas facing the tide and anchored with

[1]Upstream during the downstream migrations in the spring.

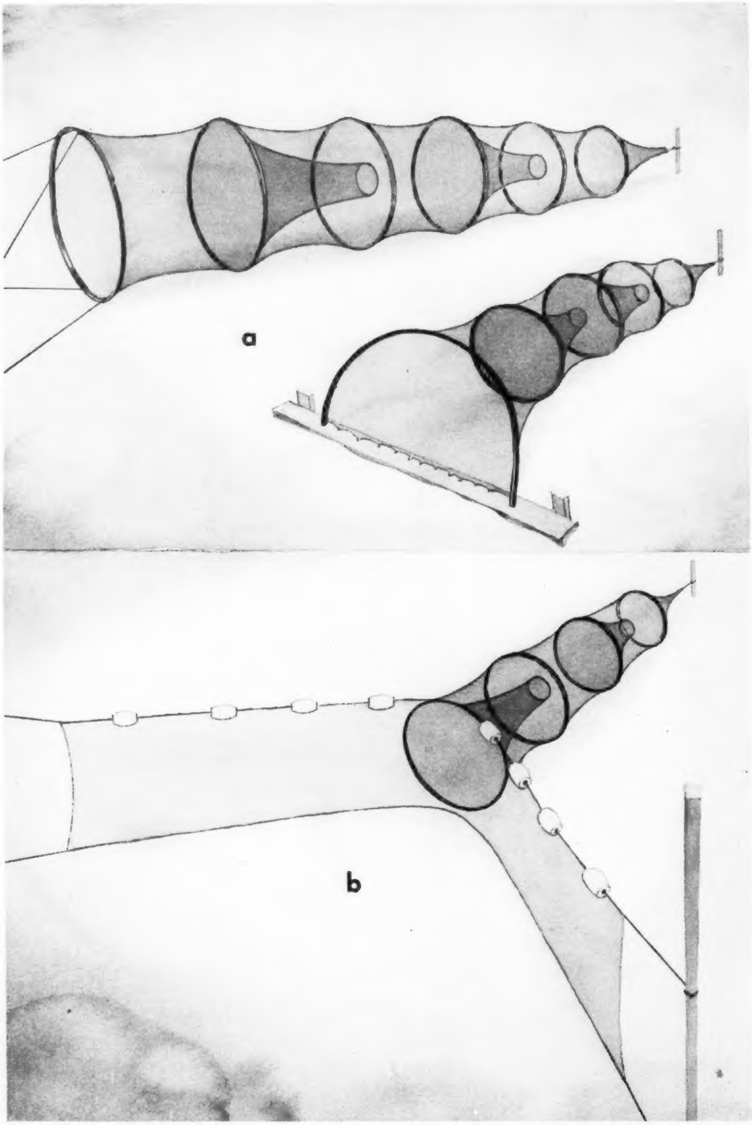


Figure 3.—Hoop net (a) and fyke net (b) (after Dumont and Sundstrom, 1961).

ballast or rocks, bricks, or cement. The number of pots set should be limited to those that can be tended daily.

In addition to baited traps, a variety of unbaited traps and nets are used. Gear of this type depends on leading the prey into an easily accessible opening from which the return is restricted—just the same principle as in the baited traps except now the eel is diverted from his course of travel into the trap rather than entering it actively to seek the bait. The most common examples of the unbaited trap are the hoop net or the fyke net. A hoop net is made by covering hoops or frames with netting or wire mesh. They are usually of decreasing size from front to back and have one or more funnel-shaped openings inside. The mouth of the net can be several feet in diameter and tapers down to a small terminal hoop (Fig. 3). A fyke net is a hoop net with one or two leaders or wings extending out from the opening to lead the fish into it. These traps work best where they can be so located in a restricted body of water that the fish cannot get around them.

Hooks can also be used to catch eels. These are generally put out in sets and the method of fishing called trawling, longlining, or trotline. The gear consists of a long line to which shorter and lighter lines with hooks are attached at intervals. At each end of the line will be a weight or an anchor attached to a float or buoy. In rivers and streams, one, or both, ends of the line may be tied to a tree or stake on the bank. Eels can be taken from spring to fall by hooks. However, hooks are more apt to injure or kill the eels than are traps. This is important if the intended market for eels demands live delivery.

Another method of catching eels involves a line but no hook. A single line is fished by hand or with a rod and reel. Worms are threaded end to end by means of a dull needle. Several worms are threaded on the line, then the worms and line are formed into loops by winding around one's fingers. The loops are tied together then fastened to the end of the fishing line. The bait is fished on or near the bottom. When the eel bites, steady but gentle pressure is kept on the line until the eel is lifted out of the water. The eel has many small teeth that become entangled in the baited loops; and if the line is pulled in steadily, they will not fall off. In England, a length of wool may be used to thread the worms and the method of fishing called "bobbing." This is primarily a sportfishing method and is used on warm summer nights.

In the winter when the eels bury themselves in mud, they can be taken by spears. The inactive eels will be found concentrated around entrances to lakes or rivers or streams or in deep holes near tidal entrances to fresh water or estuaries. The taking of eels by spears or forks is called spearing, gigging, or in England—"pritching." This method was used in colonial times in the United States and is still the same

today. Since the eels are often killed by this method, it is used mainly for sports purposes where the eels will be consumed soon after catching. The secret of success to this method is to find where there is a concentration of eels buried in the mud. Once a suitable spot is located, it can usually be used year after year, and the easiest way of finding such a spot is to contact someone who has speared eels in the past. In cold weather, a hole can be chopped in the ice. A three (or more) pronged spear is used with a long handle. The prongs of the spear are usually barbed. Some spears will have an unbarbed center prong with the barbs on the two outside prongs facing in. A variation of this type spear is one that has an unbarbed center prong and two outside spiny loaded clamps that prevent the eel from wriggling off the center prong. Other methods use a spear with serrated blades. When the spear is pushed down on the eel, it is forced up between two of the serrated blades. The eel is thus imprisoned between the teeth but not pierced.

Silver Eels

Silver eels are the most desirable for smoking as they have a high fat content. They have fattened in preparation for the long marine migration during which they cannot feed. During the fall run, silver eels can be caught in large numbers by various forms of unbaited traps and nets. Some of the traps designed for fishing silver eels are very elaborate and require considerable time and expense to construct. Obviously, these more elaborate traps are only used where the commercial harvest is sufficient to justify their expense.

By and large, eel fishing has not reached the stage of commercial development where these elaborate methods of trapping are used. In Canada, one type of trap or weir is built in the summer when the rivers are lowest by making a large V in the river with the small end downstream. The wings or sides of the V may be made of stones, branches, brush, poles, or planks. These wings must be strong enough to resist the flow of water and the impact of floating debris. The wings lead to a sluiceway or capture box that must be so designed as to permit ready passage of water while retaining the eels. Eales (1968) reports that "at St. Jean (Iberville), Quebec, a highly profitable weir has been operated at the same site for more than 100 years by five generations of a family. The catches have averaged about 60,000 pounds (27.2 t) per year and have recently[2] climbed to 100,000 pounds (45.4 t) per year."

Sorting wild-harvested eels to remove those below market size. Photo courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

The construction of weirs varies depending on the water conditions and the materials at hand and local regulations. They all are designed to lead the eels during their downstream migration into an area from which they cannot escape. Less elaborate means, such as fyke nets and hoop nets described for catching yellow eels, can be used in smaller streams.

One thing must be kept in mind in catching eels. Since most of the fishery takes place in fresh water, State and local regulations should be carefully considered before any method is attempted. The more elaborate weirs and traps actually block off a whole section of the river, and generally the placement of such devices must be cleared and approved by the appropriate authorities.

[2] 1968.

STORAGE AND TRANSPORT

Elvers

The demand for elvers is for use in stocking natural bodies of water or for culture purposes. This means that the elvers must be held and transported alive if they are to have any market value. At the present time, the demand for elvers is primarily in Japan and to a lesser extent, Europe, so that transportation for considerable distances is involved.

After being caught, the elvers can be held temporarily in small holding nets until a sufficient quantity is accumulated for transporting them to shore. The most important consideration in holding elvers is to ensure a sufficient supply of oxygen—about 11 ppm. A holding pen or box about 2 feet × 4 feet × 2 feet (61 cm × 120 cm × 61 cm) with small mesh screens on the ends can be used near the point of catch. This box should be placed in a flow of water so the water will pass through the box. With a good water flow, about 20 pounds (9.1 kg) of elvers can be held in a box this size. The screen must be cleaned daily to ensure a good flow of water and any dead elvers removed.

A collecting station ashore can use a natural flow of water to maintain the

oxygen level. In any event, only natural, unchlorinated water should be used. Since the elvers instinctively swim upstream, any holding pen using a natural flow of water should not be overstocked, as the elvers will bunch up at the upstream end and may suffocate.

Elvers can be transported for short distances in aerated tanks. For overseas shipment by air, the Japanese prefer shipping them on ice. About 10 pounds (4.5 kg) of elvers are placed in a specially designed Styrofoam[3] container. The elvers are mixed with crushed ice and the containers packed in 50-pound (22.7-kg) master cartons. A similar unit is made of expanded polystyrene, measures 32½ inches × 3½ feet × 4 feet (0.83 m × 0.89 m × 1.2 m) and weighs only 8 ounces (227 g). A slitted sliding top provides ventilation. Each box holds 4 pounds (1.8 kg) of elvers. A separate section inside the box holds a 2½-pound (1.1-kg) cake of ice which provides cool fresh water as it melts.

Yellow and Silver Eels

Both the small domestic market for eels and the European market pay a premium for live eels. It is usually desirable to hold eels for a week or two in running water to purge them and to eliminate any muddy flavor. Any enclosed pen or box that permits a flow of water through it will do for a holding station as long as it is tended to ensure a flow of water and to eliminate dead eels. (Handling of dead eels will be discussed in the section on processing.)

Eels are normally collected with a truck with one or more tanks. One arrangement uses a paired series of small tanks on a flatbed truck. Each tank is filled with fresh potable water. An aeration unit is mounted on each tank to provide oxygen. Other arrangements utilize small tank trucks or large tanks mounted singly or in pairs. As long as the eels are not overcrowded and aeration is sufficient, little difficulty is encountered in transporting eels several hours, even in hot weather.

Eales (1968) lists several points that should be considered in designing a holding container for live eels: 1) With a constant supply of aerated water, 100 cubic feet (3 m^3) of water will hold 1,500 pounds (682 kg) of eels. If the rate of water supply is limited, the eel-water ratio should be substantially limited. 2) Remove dead eels as soon as possible from the container. 3) The inside of the tank should be smooth to prevent abrasion of eels. 4) Handle live eels as little as possible to prevent loss of slime. The slime layer aids the eels in maintaining their salt balance, and loss of this protection may cause death. 5) Be sure the openings around the container are small as eels can escape from very narrow openings. Variations of these tanks have been used. In England, one company used a barge with a perforated steel bottom. The barge is kept afloat by two buoyancy tanks and can hold a million pounds (454 t) of eels. The Dutch have used ships to pick up eels from Canada, the United States, Europe, and Africa. One of the ships, *Mercurius*, is a 300-ton (272-t) converted naval landing craft which uses circulating seawater. The other ship has a perforated hold which permits free exchange of water with the surrounding sea. Eels transported this way are subject to whatever sources of pollution are present in the surrounding water, and one shipment of eels was killed in the St. Lawrence waterway by a temporary pollution condition.

In Great Britain, tray boxes are used for transporting live eels from Ireland to London. The unit consists of an outer case 36 inches × 18 inches × 14 inches (0.91 m × 0.46 m × 0.36 m) made of ½-inch (12.5-mm) pine. Each case has five trays about 2 inches (50.8 mm) deep. Each tray is divided into two compartments. The four bottom trays are packed with about 20 pounds (9 kg) of eels each. The top tray is filled with crushed ice. All the trays have 20 half-inch (12.5-mm) holes in the bottom so the melt water trickles down over the eels in all the lower trays.

Air shipping live eels from the United States to Europe is done by packing them in 30-pound (13.6-kg) lots in polyethylene bags. The bags are vented near the top and contain a small piece of ice. The bags are packed in wax-impregnated boxes. For air shipment, it is very important that the containers are water-tight to prevent leakage in transit.

Eels can be held for several months without feeding. However, in general, it is probably not a good idea to hold them for more than a few weeks. If longer storage is necessary, the eels should have access to salt water occasionally; otherwise, they tend to get hard and lose their wriggling characteristics. They should not remain in salt water more than 24-48 hours at a time or they may lose their slime and die (Eales, 1968).

PROCESSING

Frozen Live Eels

As mentioned in the previous section, the most lucrative market for U.S. eels is in Europe. This market pays highest price for live eels. Shipment of live eels poses several problems connected with packing methods, transport scheduling, and possible delays en route. Eels that die in transit may not be accepted at all; or if they are, the price is greatly reduced. An alternate way of marketing is to ship the eels in frozen form. This reduces the price received but also reduces the risk involved in shipping live eels.

Eels should be held in fresh water for 1-2 weeks after capture to permit them to clean, or purge, themselves of feed. This also helps to eliminate any off flavor that might be present with eels taken in muddy water. The eels are then size graded, with the most common sizes being ¼-½ pound (0.11-0.23 kg), ½-1 pound (0.23-0.45 kg), and over 1 pound (>0.45 kg). The graded eels are packed live in 25-pound (11.4-kg) lots in plastic bags which are, in turn, inside a wax-impregnated corrugated cardboard box. Freezing should be done rapidly at −40°F (−40°C). During the freezing process, the eels will intertwine. The European buyers look for this condition, and if it is not present consider this evidence the eel was dead when it was frozen and may reject the entire lot. Usually two of the cardboard cartons are packed in an

[3]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

insulated master carton for air shipment or in uninsulated master cartons for shipment by refrigerated ship. The cost of the latter method is considerably less, and if a sufficient volume is involved would be the preferred shipping method on the basis of economic considerations.

Killing and Cleaning

Most of the eels consumed throughout the world are smoked. Jellied eels are preferred in parts of England. Limited amounts are used as fresh or frozen eels. Most of the U.S. eels frozen alive and sent to Europe will be used for smoking.

Live eels can be killed by placing them in a container and liberally sprinkling them with salt. They should not be buried in the salt; just a good sprinkling will do. They should be left for about 2 hours. This process also aids in removing the slime. Electro-killing has been tried by placing the eels in water and then passing an electric current through the container. This will kill the eels but presents possible safety hazards for the workers and still leaves the problem of getting rid of the slime.

Once the eels are dead, the slime can be seen floating on the surface of the brine. The slimy water is poured off and the eels thoroughly washed in fresh water. This may take up to a half hour in cold water, after which they are scraped or scrubbed to remove any remaining traces of slime. It is important to remove all slime since failure to do so may affect the flavor of the finished product. If the eels are to be smoked with skin on, the scrubbing will also improve the appearance.

Once the eels are washed, they are gutted. If the eels are to be used in the skinned form, it is easier to skin them before gutting. To skin, fasten the eel with a nail or clamping device on the head in a vertical position. Make a circular cut about three inches behind the head. The cut should not penetrate the flesh as there is a danger of cutting into the gall bladder, and this can cause off flavor. Also, care should be taken to avoid contact through an open cut with the blood from the eel because of its toxic properties mentioned earlier. Next, lay the skin back from the cut and strip it off intact using a pair of pliers.

Gutting the skinned or unskinned eels is facilitated by sprinkling salt or sawdust on it or dipping one's hands in salt or using a rough cloth to hold and getting a good grip on the fish. With a sharp knife, make a shallow cut from the gills to a point about 2 inches past the vent (to expose the kidney). In removing the viscera, a knife with a rounded, blunt end and a serrated edge is helpful. The rounded part of the knife is used to separate the lower part of the gut from the body cavity near the vent. The serrated edge is used to remove the blood vessel along the backbone and the kidney. The knife is then slid forward to complete removal of the viscera (Lynch, 1964). Scrub out the gut cavity to remove all traces of blood and rinse with cold water.

If the eels will not be further processed, it is advisable to remove the head and the last 2-3 inches (50 to 75 mm) from the tail. The eels can then be cooked fresh or frozen. If frozen, they should be packaged in a good gas/vapor proof material. Eels, especially silver eels, have a high fat content and unless adequately protected during frozen storage may develop rancidity (Berg et al., 1975).

PREPARATION OF EELS

Fresh or Frozen Eels

Eels can be used fresh or frozen for frying, baking, smoking, or gelling. Fresh eels are preferred for gelling, and eels for smoking should have the head and skin left on.

Fried eels are prepared by starting with a cleaned and skinned eel cut into 3-inch sections. Wipe the sections dry and dip in an egg batter then in bread crumbs. Deep fat fry at 375°F (190°C) for 3-5 minutes. A more elaborate Italian recipe is Eel Neapolitan:

1½ pounds (0.7 kg) of dressed eels
3 tablespoons olive oil
1 clove sliced garlic
1 medium can of peeled tomatoes
½ teaspoon salt
½ teaspoon pepper
4 thin slices of Italian bread, toasted
10 ripe (black) olives, chopped
1 tablespoon seedless raisins
½ cup water

Cut the eel into 2- to 3-inch (51- to 76-mm) pieces. Brown garlic in oil. Remove the garlic from the pan and add tomatoes, salt, pepper, and eel. Cook 10 minutes then add olives, raisins, and water. Cover pan and cook about 20 minutes or until the eel is tender (cooking time will vary depending on size of eel). Place slices of toast in a dish and pour the mixture over them. Serve hot.

Smoked Eels

Smoking has been the traditional way of preparing eels. They are one of the most important smoked fish products in Germany and the Netherlands. Eels may be smoked from either the fresh or frozen state, although fresh eels are reported to give a better finished product. Frozen eels thawed and deslimed are dressed as described earlier. Skin and heads remain on. Large eels may be cut into two sections before smoking, but most eels are smoked whole.

An Australian method of smoking, based on the German method, is as follows: Eels weighing 9-14 ounces (257-400 g) are cleaned and dressed. They are placed in a brine. The brine concentration may be as low as 10 percent for 24 hours, but unless cooled with ice, the eels may spoil before the brining process is complete. In hot weather, more often a strong brine (100 ppt salinometer) is used. The time will vary from 2 to 24 hours, depending on the degree of salt desired. After removal from the brine, they are washed with fresh water and air dried. The eels are then hung by the head on hooks and dipped in boiling water until the sides open out. The fish are then placed in the smokehouse and given a two-stage hot smoke.

In the first stage, hardwood chips are burned to give clean hot flames and quickly bring the temperature up to 248-257°F (120-129°C). This temperature is maintained for 5-10 minutes so the eels are partially cooked and oil and water content is lowered. In the second stage, the flames are smothered with damp chips and the draft reduced to

Smoked eels. Photo courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

produce a heavy smoke. The temperature is lowered to 104-122°F (40-50°C). Smoking time is from 90 minutes to 4 hours, depending on the size of the eels; although for some markets, this time can be extended to as long as 12 hours. The eels are then cooled in the smokehouse and given a light brushing of edible oil on the outside to improve appearance. Yield is about 60 percent of live weight (5-10 percent loss in gutting and about 30 percent loss during the hot smoke process) (Anonymous, 1955).

Another method used in England in a mechanical smokehouse calls for using eels ¾ to 1½ pounds (0.34 to 0.68 kg). The eels are brined (lightly for domestic use and heavier for export) and smoked for 1 hour at 95°F (35°C), 30 minutes at 120°F (49°C), and finally at 170°F (77°C) for 1 hour. The smoking loss is about 15-20 percent by this method. The smoked eels must be refrigerated and have a chilled storage life of 3-4 days (Horne and Birnie, 1969). It should be noted that any smoking of eels for sale in the United States must be done according to the guidelines established for smoked fish by the U.S. Food and Drug Administration.

Smoked eels may be sold chilled, frozen, or canned as a fully preserved product. Chilled smoked eels have a relatively short storage life and must be properly refrigerated at all times. Frozen smoked eels require the same type of package protection as do unsmoked eels.

Jellied Eels

The method given for preparation of jellied eels is used commercially in Great Britain where this product is popular. Eels are cleaned, dressed, skinned, and cut into 2-inch (51-mm) pieces. The pieces are parboiled for 10 minutes in water with 2 percent vinegar, 3 percent salt, and 2 ounces (57 g) of mixed pickling spices per gallon. After cooking, the pieces are drained, cooled, and packed in glass jars or flat cans and covered with a 10 percent gelatine solution containing 1 percent acetic acid and a few drops of lemon essence. The containers are vacuum sealed and heat processed. The process may be varied by using a spiced vinegar-salt solution to cover the cooked meats in the container (Horne and Birnie, 1969).

Proximate Composition

The fat content of eels is highly variable. Silver eels will usually have a higher fat content than yellow eels. The content of the American yellow eels, edible portion only, is about 72 percent water, 19 percent protein, 9 percent fat, and 1 percent mineral or ash. For smoked eels, edible portion, it is 50 percent water, 19 percent protein, 28 percent fat, and 2 percent ash (Chatfield and Adams, 1940). Typical composition of raw European silver eels is 58-60 percent water, 14 percent protein, and 26-28 percent fat. Because of the high fat content of silver eels, the calorie value can be as high as 1,350 calories/pound (0.45 kg) (Horne and Birnie, 1969).

MARKETS

Since the days of the early American colonists, there has been a steady, but small, commercial fishery for eels in the United States. For the 40 years preceding 1974, the domestic catch of eels had been fairly constant between 1.3 and 2.5 million pounds (590 and 1,134 t) annually. Nearly all of these eels went to satisfy domestic ethnic markets primarily in the large population centers of the northeast. It is only in the last few years that interest has developed in the possibility of expanding our eel fisheries to meet the increasing demand, and correspondingly higher prices, of the export market.

Elver Market

The market for elvers has been stimulated by the failure of commercial harvest in Europe and Japan to satisfy local demands. This has led to an increased interest in eel culture in Europe and an expanded interest in the long-established culture operations in Japan. Spain is the only country where there is a direct market for elvers for food purposes. All other markets seek elvers for use in stocking natural waterways or for eel culture.

Germany, Netherlands, England, and France are all exploring eel culture operations. The primary market for elvers at this time, however, is Japan. Reports on the prices paid for elvers have varied widely. A range of value from $50 to $900 per pound (the higher price was for small elvers running 7,000 and over count per pound) was reported in Maine (Ricker and Squires, 1974). The U.S. Regional Fisheries Attache in Tokyo reported that one Japanese firm quoted a retail price for Japanese elvers of $417 per pound in 1973 (Folsom, 1973). However, American elvers are not considered as desirable by the Japanese as their local species, and these reported high prices should not be expected by anyone seeking to go into the export elver market in this country.

Maine fishermen have been interested in the Japanese elver market. Prices received are much lower than the figures cited above would indicate—about $20-$99/pound (0.45 kg) for Asian eels and $14/pound (0.45 kg) for European elvers. In 1971 and 1972, the Japanese paid an average of approximately $12 and $4/pound (0.45 kg) for U.S. elvers.

There are several reasons why American and European elvers bring a lower price on the Japanese market. The smaller the elver, the higher the price. That means that the young glass eels are highest in value. There is the problem of shipping them so they arrive alive and remain in good condition after they are stocked. The price paid reflects

this risk. The American elvers are received later in the growing season than the Japanese elvers, and this has an adverse effect on their growth and eventual time of marketing. The American (and European) eels are adapted to cooler water than their Asian counterparts and grow slower, and the Asian eels are collected at a younger age so there are more per pound.

Despite these drawbacks, it would appear that the Japanese demand for elvers will continue to grow. This means that there is a potential for the development of a U.S. export market for elvers. Astronomical prices should not be expected, however, and any entry into this field should be done with caution until the holding and shipping techniques are well developed and the market established (Folsom, 1973). While the price received per pound is relatively high, there are several risks involved in the part of the supplier; the greatest being the death of the elver in transit. Prices received for elvers must cover the costs of catching, buying the elvers locally, construction and operation of pickup facilities and holding stations, packing materials, and air freight and marketing fees. The profit margin should be carefully examined before a large scale elver operation is launched.

Markets for Adult Eels

The market for larger eels is primarily in Europe, although there may be some potential in Japan as well. In 1972, Japanese importers were offering $1.23 to $1.36/pound (0.45 kg) of live eels weighing 150-200 g (about 6-8 ounces). For frozen eels of the same size, the price was 22-27 cents/pound (0.45 kg). In contrast, $2.50-$3.00/pound (0.45 kg) was the price for Asian eels (Folsom, 1973).

In 1972 a firm delivered 70 tons (64 t) of live eels by air freight to England. Mortality rates were generally under 2 percent. Live eels are flown to Germany from several east coast States, particularly from Maine, Massachusetts, Pennsylvania, Virginia, and North Carolina. Prices paid to New England fishermen have generally been in the 25-35 cents/pound (0.45 kg) range. One dealer in North Carolina paid an average price to fishermen in 1972 of 23 cents/pound (0.45 kg) and in 1973, 45 cents/pound (0.45 kg). Dealers in North Carolina and Virginia have shipped frozen eels to Europe, primarily Germany, for further processing as smoked eels. The price for frozen eels is much less than for live eels. The relative prices are similar to those quoted for the Japanese market.

The export market would seem to offer the greatest potential for expansion. The domestic ethnic market in the northeast is quite stable, and the possibility of expanding domestic consumption in the near future is limited without a considerable marketing and promotion effort.

EEL CULTURE

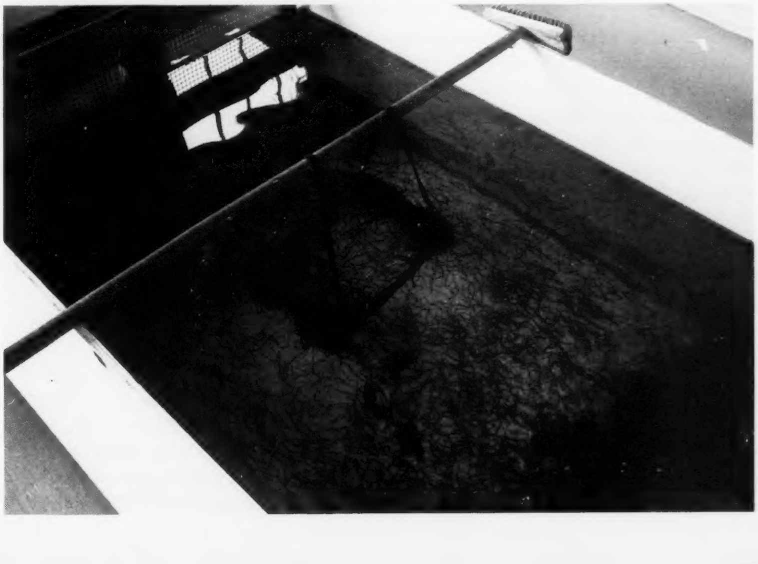
As the demand for eels throughout the world continues to grow and as supplies of readily available wild eels becomes more restricted, the interest in culture of eels increases. Eel culture is not a new technique and involves catching elvers and placing them in a suitable environment for growth to market size. Elvers were thus reported to have been transported and raised in ponds in Macedonia over 2,000 years ago. The next step beyond transporting of elvers to natural bodies of water is to place them in specially constructed ponds and this is eel culture.

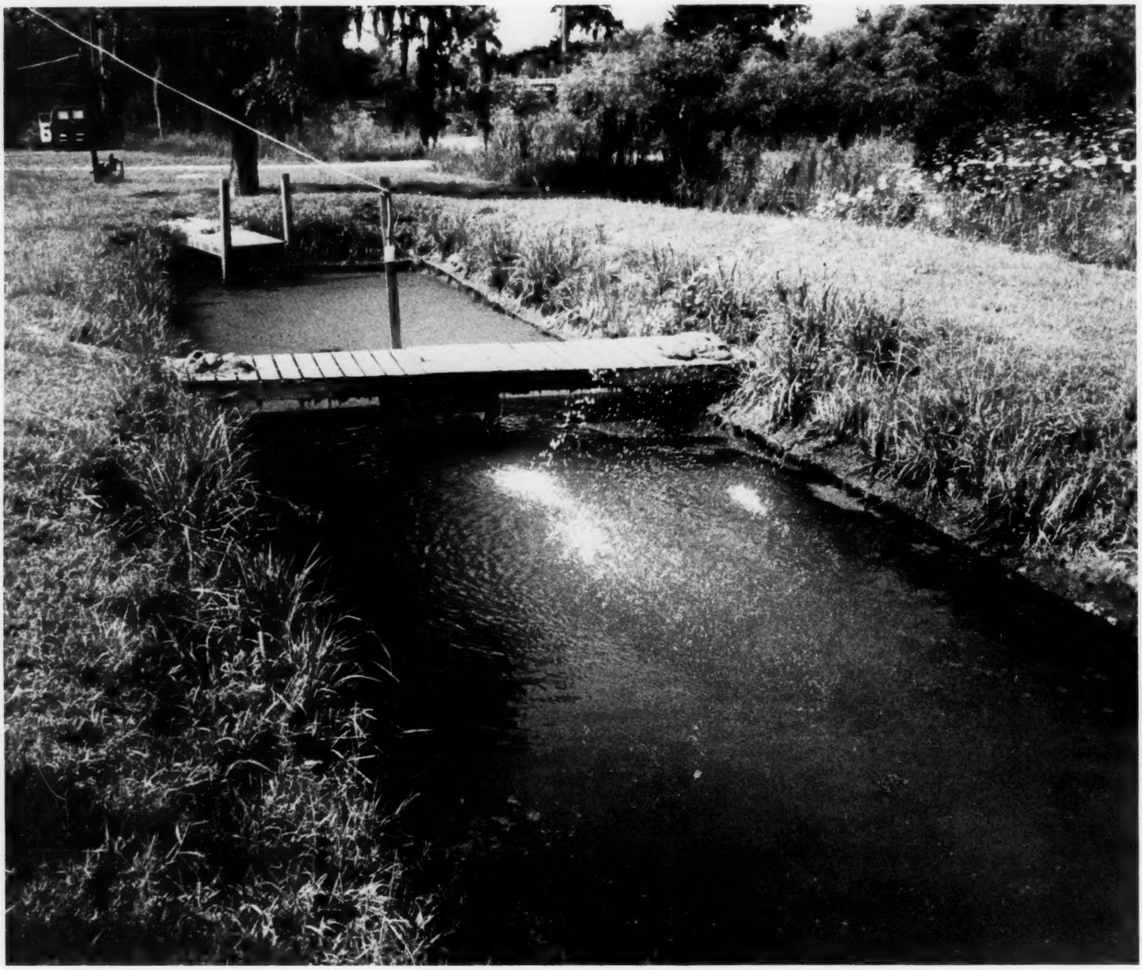
Culture, as used here, means that something is done to assist or control the growth of eels that is different from the natural or wild state. Transporting elvers to a natural body of water where they live and grow on whatever food is available and then are harvested as any wild fish would be is the simplest form of culture under this definition. This is what the Macedonians did and it is the method used for centuries in the Valli of Comacchio in Italy. This is a lagoon of 80,000 acres (32,389 hectares) located between two branches of the Po Delta and divided by dikes. It provides about 2 million pounds of eels per year (Eales, 1968).

A more controlled culture method is one that uses natural or artificially constructed bodies of water where controlled feeding, management, and harvesting are practiced.

The Japanese have practiced controlled culture of eels since 1879. Eel culture did not become a significant source of supply in Japan until the early 1960's. In 1962 about 7,600 tons (6,893 t) of cultured eels were harvested in Japan. By 1969, this increased to 23,000 tons (20,861 t). A year later the production of cultured

An indoor tank holding 5 kg of elvers for parasite and disease treatment and initial feeding. Food is placed in the wire mesh tray at center. Photograph courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.





A small outdoor pond in which eels are grown to market size (¼-½ pound). Photograph courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.

eels was sharply reduced to 16,700 tons (15,147 t) due to a disease that affects the gills and kidneys of the eels. Thousands of eels died and losses were in the millions of dollars. This disease was thought to come from the first elvers imported from Europe in 1969 (Folsom, 1973).

Although Japan has the best established eel culture operation, interest is increasing in Europe and the United States. In the United States, an experimental eel culture operation has been started by the University of North Carolina. In Europe, eel culture activities are being carried out in Spain, Italy, Great Britain, and France (Angel and Jones, 1974). New Zealand has at least two eel culture operations also. Taiwan began experimenting with eel culture in 1967. In 6 years, the industry rapidly expanded, and in 1973, an estimated 10,000 tons (9,070 t) of eels were raised (Forrest, 1974).

Most of the European culture operations rely on natural sources of feed. More intensive methods are under investigation or are in the experimental stages, however. The Japanese pond culture of eels is described by J. F. Sanders in the publication *Australian Fisheries* (Folsom, 1973) as follows:

"Elvers are caught in the winter as they migrate upstream from the spawning grounds in the open sea, and are cultured in relatively small ponds of 150 to 350 square meters by 70 cm deep. This phase of culture lasts for about one year, during which time the young eels grow to about 20 gm in weight. The original stocking density is about 500 to 600 gm per square meter.

"The growth of individual eels is tremendously variable and constant culling is required during all stages of culture to ensure approximately uniform sizes in each pond.

"When elvers begin feeding they

are given small oligochaete worms for about two to three days, then for seven to ten days a paste of mixed oligochaete worms and fish flesh. Then they are weaned on to fish flesh or synthetic diets especially formulated for eels. They are fed twice a day and the quantity of feed given is about 30 percent of body weight.

"Young eels prefer to eat in a darkened place and feeding is done in a shelter at one side of the pond. The food is placed in a wire basket suspended just above the water to prevent undue contamination of the water. When young eels reach a weight of 20 gm they are ready for the next phase which takes them to adulthood.

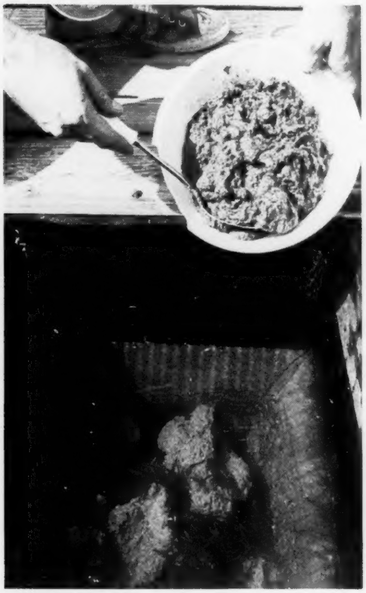
"The aim of adult culture is to produce 150 gm eels for market and this is achieved in about two years from the elver stage, which is double the growth rate of wild eels. The size of the adult ponds is about 3,000 to 10,000 square meters by 50 cm deep. The stocking rate is about 500-700 gm of seed eels per square meter of pond. Growth is most rapid during April to October and during the period the eels must be fed as much as possible. The quantity of food supplied is about 10 percent of body weight and is fresh or frozen fish flesh or synthetic diets. If fish flesh is used the feed coefficient is 6 to 7 while for synthetic diets it is less than two. (Feed coefficient is pounds feed required per pound of weight gain.)

"During culture care must be taken to maintain a satisfactory water quality. As all phases of culture are in still water and the density of stocking is high, the maintenance of water quality is relatively difficult. pH levels in the water should be about 8.0 to 9.2 during the daytime, and about 6.8 to 7.2 at night.

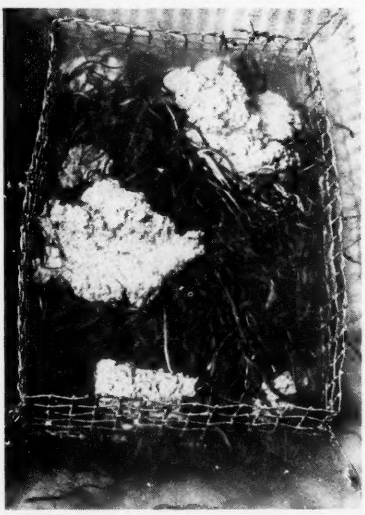
"Ponds located on acid soils usually have a pH around 5.5 to 6.5 which is too low for satisfactory eel culture. A high dissolved oxygen level is absolutely necessary and the minimum desirable value for eels is 2.0 to 2.5 cc per litre. Water wheels which oxygenate and mix water layers are a common feature of eel ponds. Satisfactory levels of calcium nitrate and phosphate should be maintained and this can often be done by the addition of fertilizers.

"Ponds are usually drained and the bottom mud turned and sprinkled with lime at the end of each year.

"The species composition and abundance of micro-organisms is of considerable importance during eel culture. In general phytoplankton are beneficial to eel culture and zooplankton are not. Well managed eel ponds are a blue-green color, with a plankton composition of 0.3 to 2.9 percent zooplankton and 97.1 to 99.7 percent phytoplankton."



Placing food in a feeding tray (above) in the outdoor pond. Below, young eels consume the prepared diet. Photographs courtesy of the North Carolina State University Eel Culture Project, a part of the University of North Carolina Sea Grant Program.



Disease control is an important factor in a successful culture operation. There are some 10 different types of disease that affect Japanese eels, and any one of them is capable of wiping out an eel farm overnight (Folsom, 1973). European and American eels also are susceptible to disease although the types and extent of the problem are not as yet as well defined. To date, eels have not been spawned successfully in captivity thus the importance of obtaining elvers to start the culture process.

Despite the problems facing the culturist, the potential for gain is great. If one started with a pound of elvers containing 2,000 individuals and had a survival rate of 80 percent by the time they reached a half pound, there would be an 800-fold increase in weight. If the elvers cost $30 and the finished product brought $1.25 per pound, this would be $1,000 or an increase in value of 33-fold. Balanced against this potential increase in value is the risk of loss through disease or a depressed market that could lower the prices. Also, there is the cost of feed, labor, facilities, transportation, and marketing to be considered. Any would-be culturist would be well advised to start on a small basis and develop the necessary information relative to the conditions where the operation is to take place, before investing large sums of money in a large-scale culture operation.

SUMMARY

We have reviewed some of the characteristics of the genus *Anguilla*, the common eel. This fascinating creature is a true fish with a unique life cycle that is still not fully understood. The European species spawns in the Sargasso Sea, and the American species is thought to spawn somewhere to the west of its European relative. After spawning, the young leptocephali travel toward their respective continents. For the European eel, this trip

lasts 3 years, while the American eel completes the journey in about 1 year. When they reach the coast, the leaf-like leptocephali undergo metamorphosis to glass eels and then to pigmented elvers. Females head upstream into fresh water while males stay near the coast. They spend several years here as yellow eels. Finally, they change to silver eels and begin the reverse migration to their breeding area where they spawn and die.

Eels have an ancient and well-established following of avid consumers in Europe and parts of Asia, particularly in Japan, but are relatively unutilized in the United States. World catch, fishing methods, processing, preparation techniques, and information on eel culture throughout the world were also covered.

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MFR PAPER 1304

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Status of the Herring Stocks Fished by the Federal Republic of Germany Fleet

HOLGER DORNHEIM

The findings presented in this paper are mostly derived from the results and conclusions drawn at: 1) A March 1977 meeting in Copenhagen, Denmark, by the International Council for the Exploration of the Sea's (ICES) Sea Herring Assessment Working Group for the North Sea, Celtic Sea, and Hebrides stocks in the area south of lat. 62°N; 2) an April 1977 meeting in Bergen, Norway, by ICES's Atlanto-Scandian Working Group for the Norwegian Sea stock; and 3) several 1976 meetings by an International Commission for the Northwest Atlantic Fisheries working group for the Georges Bank stock. Each of the five stocks mentioned above will be dealt with individually.

NORTH SEA

North Sea catches, including the Skagerrak and English Channel catches, are shown in Figure 1. The total catch amounted to 183,000 metric tons (t) for 1976 even though the Northeast Atlantic Fishery Commission (NEAFC) only had approved a 160,000-t quota for the total area. In particular, the following picture is shown: In the eastern part of the northern North Sea, catches decreased from 9,700 t in 1975 to 2,500 t in 1976, while in the western part of this area catches increased slightly from 96,000 t in 1975 to 108,000 t in 1976. In the central North Sea, catches declined from 182,000 t in 1975 to only 46,000 t in 1976, which is approximately a 75 percent decrease. With respect to the central North Sea catches, the fishery for herring for direct human consumption dropped from 91,000 t in 1975 to 39,000 t in 1976, while the young herring fishery (i.e., fishery for fish meal) decreased from 91,000 t in 1975 to less than 8,000 t in 1976. However, it must be stressed that in1976 it was forbidden to catch herring only for fish meal. In the southern part of the North Sea, including the English Channel, catches decreased from 26,000 t in 1975 to 12,000 t in 1976, thus by more than one-half. Out of these figures it is quite clear that with the exception of the western part of the northern North Sea, in all other areas there occurred a slightly more than drastic decrease of herring catches in 1976. These results, which cover the whole North Sea, show the lowest catches since herring fishery records were first kept with the exception of the war years of 1915-1917 and 1941-1942.

What are the reasons for this development? In the middle 1960's the high fishing effort led to high yields and, consequently, to the first serious reductions in stock abundance as shown by small numbers of larvae, high mortality rates, and low catch per unit of effort. These serious indications of stock depletion were recognized and subsequently fostered several different countermeasures: 1) Closure of spawning areas; 2) establishment of minimum sizes of 20-23 cm; 3) closure of specific areas or seasons; and 4) reduction of fishing effort or catch quotas. However, only starting in 1971 did the NEAFC agree upon a closure of the total North Sea area both in May and from 20 August to 30 September. Similar regulations were in force for 1972, 1973, and 1974. In the middle of 1974 a catch quota system for the different nations was established after the system of closed seasons had shown itself ineffective. This quota system is still in force.

Meanwhile, the herring catch in the North Sea has been totally prohibited by a decision of the Ministry Council of the European Economic Community (only the Netherlands was allowed to catch any fish (1,500 t) in June). Thus the questions are: What does the herring situation look like just now; what kind of biological facts caused the closure of the North Sea for all directed herring fisheries; and what does the picture look like for the near future?

First of all, the total catch in 1976 amounted to only a little bit more than one-half of the already low 1975 catch. Despite the recruitment of the relatively

Figure 1.—International herring catches (× 1,000 t) in the North Sea and Norwegian Sea during 1960-1976 (1976 values are preliminary).

strong 1973 year class to the 1976 spawning population, this spawning population amounts to only 155,000 t after taking into consideration the 1976 catch results. By taking the results of the 1976 international research on the number of larvae into consideration, this would result in a size of the spawning population of only 85,000 t. These figures of 155,000 t and 85,000 t, respectively, probably do not mean too much to outsiders, but they become terrifically important when it is pointed out that years ago scientists of all North Sea herring fishing nations concluded that the spawning potential should amount to about 800,000 t to guarantee a sufficient number of recruits to the stock. This latter value represents about 30 percent of the spawning stock size at the end of the 1940's when the total stock was only slightly fished.

The picture of the North Sea herring stock becomes even dimmer when one looks at the strength of the 1974 and 1975 year classes which will recruit to the spawning stock in 1977 and 1978, respectively. All indications, including the catches of the mixed fisheries which operated with minimum mesh sizes (NEAFC's "Recommendation No. 2" on fisheries) and yielded only the extremely low level of 8,000 t in 1976, show that both year classes are extremely weak.

The fishery in 1976 on adult herring was, like in 1975, mainly dependent on one year class, namely the 1973 one. This year class contributed 74 percent in numbers of the total 1976 catch of the 2-year-old and older herring. Besides the facts that, 1) The 1974 and 1975 year classes are very weak; 2) the spawning stock amounts—as mentioned above—to only 155,000 t, or even to only 85,000 t; and 3) the fishery on herring for direct human consumption depends on only one year class, namely the 1973 one, it is now apparent that the first results of the larvae investigations in 1976 indicate that this year class is weak, too. By looking at these facts it is obvious that the herring stock in the North Sea is at this time in very bad shape. It is even worse than anticipated by experts the year before and will probably deteriorate in the near future or even no longer exist if decisive and drastic steps are not immediately taken. The Herring Assessment Working Group recommended, therefore, an instantaneous and total ban on all types of directed herring fisheries in the North Sea to avoid the threatening danger of a total and final breakdown. If this recommendation comes into force and the ban is continued for 1978 and 1979, then there is a good chance that the spawning stock will reach approximately one-half of the level of the desired size, i.e., 400,000 t, by 1979 if recruitment is average. Consequently, the herring stock will improve relatively fast, provided that a fishery management regime that is directed by logic becomes effective. The basic requirement for such an improvement, of course, is a continuous monitoring of the stock during coming years. At present, however, based on this very low stock level, it cannot be stressed strongly enough that a ban on herring fishing should be in force at least for all of 1978. On the other hand, it should also be emphasized that at this current very low stock level it is very difficult to predict the stock situation more than 3 years in advance because of the natural fluctuations of which recruitment plays a part.

There is still the question of whether or not the catch of certain quantities of herring could be allowed. This question was checked by the working group, too. Calculations were made on what would result from a catch of 75,000 t and 150,000 t, respectively, in 1977 and 1978. It resulted that if a catch of 75,000 t were taken each year, then the present very low level of the stock could not be increased until 1979, even if one assumes a very low fishing mortality rate of young fish. The catch of 150,000 t in 1977 would lead to a total breakdown of the stock in 1978.

CELTIC SEA

Catches in this area for the 1976-1977 season (which extended from 1 April to 31 March) were 7,000 t, the lowest on record since 1956 (Fig. 2). Normally in this area between 20,000 t and 50,000 t are caught per year. As for the 1974-1975 and 1975-1976 seasons, the quota set by the NEAFC for 1976-1977 of 16,800 t (which later was reduced to 10,800 t) was not reached; only 65 percent of the total allowable catch was taken. In connection with this, it must be emphasized that this low total catch is not due to a reduced fishing effort, and that the fishing mortality rate of this stock has remained at more or less the same level since the 1972-1973 season. Calculations of the working group show the size of the adult herring stock to be 10,000 t as of 1 April 1976, while in the late 1960's it was on a constant level of about 80,000-90,000 t. The present low level of stock abundance is a result of a steady decline since 1972 for which two reasons are responsible: 1) A very high fishing mortality since the 1971-1972 season; and 2) a low recruitment, observed for the first time in 1970, being revealed extremely strongly during the past 2 years. Furthermore, there are indications suggesting that since 1972, herring, especially 2-year-old fish, were fished heavily, but prior to that time were subjected to only a moderate fishing mortality rate. The reason for this is indicated by the experts by an

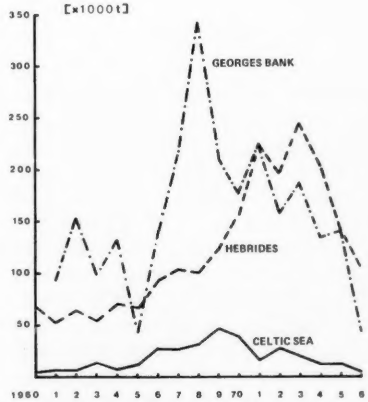

Figure 2.—International herring catches (× 1,000 t) in the Celtic Sea, Hebrides area, and on Georges Bank during 1960-1976 (1976 values are preliminary).

increase of the growth rate in connection with a lower age at sexual maturity.

The stock size of the Celtic Sea herring was estimated at 8,300 t on 1 April 1977. Thus, it follows that the quota of 6,500 t for the 1977-1978 season which was set as a precautionary measure by ICES is much too high. If this is the case, then the fishing mortality rate of all fully recruited age groups would be raised to the average level of the most recent years. This would result in a total stock size of about 11,000 t on 1 April 1978, even if recruitment is overestimated. Therefore, the working group strongly recommended a ban on the herring fishery for the whole 1977-1978 season. Even in this case, the stock on 1 April 1978 will be under the target level of 40,000 t which guarantees the survival of this stock. It also follows that a total ban for the herring fishery in this area must be enacted for the 1978-1979 season.

HEBRIDES

Another stock which is important for the FRG herring fishing fleets is the one off Scotland in the Hebrides area. International catches are shown in Figure 2. Preliminary results for 1976 show the catches at about 107,000 t, the lowest since 1969. Not even the total allowable catch agreed upon by the NEAFC (i.e., 136,000 t) was taken, but only 78 percent of the quota. This decline is mainly due to the fact that the Scottish government, following a recommendation of their own scientists, imposed catch restrictions in order to preserve the stock. These restrictions severely reduced the Scottish fishery, especially the coastal fishery of which about 30,000 t show up in the international catch statistics.

The working group checked the newest available data and determined that since 1971 the fishing mortality rate of this stock has been above the level of maximum sustainable yield and has continued to increase in the last 3 years. The adult stock reached its maximum size of 670,000 t in 1972, but decreased to less than one-half of this value by 1 January 1975.

A slight increase in stock abundance could have been obtained through the recruitment of the moderate 1973 year class in 1976, but this possible gain was mostly compensated by the heavy fishing since 1975 on the adult stock. Based on the assumption that the 1974 year class (which will recruit to the adult stock in 1977) is little above average in strength and that the aforementioned facts are correct, the strength of the total stock should be 206,000 t on 1 January 1977. This anticipated stock size would result in, not in a total catch of 83,000 t, as first proposed, but rather in one of only 48,000 t for 1977. The 1978 total allowable catch depends on that of 1977, of course. If the initially agreed upon maximum catch of 83,000 t is taken in 1977, then it would result in only 44,000 t being available in 1978. However, if the catch were restrained to 48,000 t in 1977 as proposed, then it would result in a total allowable catch of 53,000 t in 1978. By taking the latter course of action an increase of the strength of the spawning stock would be achieved, the working group concluded. Therefore, the working group recommended for the herring stock of the Hebrides area a total allowable catch in 1977 of 48,000 t, and in 1978 of 53,000 t.

NORWEGIAN SEA

Catches of the Atlanto-Scandian herring stock up to 1975 are shown in Figure 1. No figures are available for 1976, but catches will only amount to 1,000 t of mostly "small herring" and "fat herring" off the Norwegian coast. Besides other factors, the increase of catches up to 1966 was due to the occurrence of the strong 1959 year class. The sharp decline after 1966 was due both to the very high fishing effort— especially by the Norwegian purse-seiners — and to the almost complete failure of recruitment.

Steps to regulate the stock were taken by Norway and Iceland beginning in the late 1960's but it was already too late to save the stock as indicated by the catches in the following years. The spawning stock had declined to virtually nothing in 1970 and 1971; no larvae were even found on the spawning grounds. Since 1972 the spawning stock began to improve slightly, due in part to a very small segment of the 1969 year class surviving the "small herring" and "fat herring" fisheries and being able to spawn in 1973 as 4-year-old fish. In 1976 some of the 1973 year class fish recruited to the spawning stock. By 1977 all of the 1973 year class had fully recruited to the spawning stock. In addition, in 1977 some of the 3-year-old fish of the 1974 year class reached sexual maturity.

On the basis of these findings and of some tagging experiment results, the working group concluded that the spawning stock will have a size of about 200,000 t in 1977. Through investigations with hydroacoustic methods on the number of larvae present in 1975 and 1976, it was determined that both year classes were weak. It is assumed that those year classes will lead to a strong increase in stock abundance only if they are not fished. Assuming that: 1) There is no fishery on adults or juveniles; 2) the estimation of the 1975 and 1976 year class strengths is approximately correct, and; 3) these year classes fully recruit as 3- or 4-year-old fish to the stock, then the spawning stock will increase to 430,000 t in 1978 and 895,000 t in 1979. No agreement could be reached between the members of the working group on what steps should be taken to manage the stock on a seasonal basis. However, they explicitly pointed out that the spawning stock is currently at a low level.

GEORGES BANK

Finally, the herring situation in the Georges Bank area should be described. This stock was heavily fished by foreign fishing fleets, including the FRG stern trawler fleet, between 1967 and 1972 (when catch quotas were introduced). Catches since 1961, the first year for which official statistics were prepared, are shown in Figure 2. In reality, catches were supposedly higher by some 10,000 t from the mid-1960's until 1972, since data on discarded fish were only partially recorded, and the catches of nonmember countries of

ICNAF like the German Democratic Republic (GDR) did not appear in the international statistics or become incorporated in the stock assessments.

After the introduction of national quotas in 1972, catches declined in accordance with the declining total allowable catches, namely, 188,000 t, 137,000 t, and 141,000 t, respectively, in 1973, 1974, and 1975. During these years a total catch of 150,000 t was agreed upon by ICNAF. For 1976 a quota of 60,000 t was set, but according to preliminary statistics only about 43,000 t were taken. FRG catches reached their maximum of 82,000 t in 1970 and decreased in the following years corresponding to the decreased quotas. The resulting catch in 1976 was less than 9,000 t.

The last time the working group of ICNAF dealing with this stock met was more than a year ago. At the beginning of 1977, the United States was no longer an official member of ICNAF, but did participate as an observer at various ICNAF meetings. Because this herring stock is for the most part inside the U.S. 200-mile limit, the working group was dissolved for practical reasons. The last findings presented to ICNAF on the Georges Bank herring stock derived, therefore, from 1976. At that time it was decided to set the quota at 60,000 t or less per year to guarantee an adult stock size of 225,000 t. If this value of 60,000 t or less is adopted in successive years, then the adult stock should again reach a size of 500,000 t. If this stock size is achieved, then an allowable catch for foreign fleets could potentially be established again. Because there was no agreement on the stock size at the beginning of 1977, and because the 1971, 1972, and 1973 year classes were weak, the working group recommended a quota of 55,000 t for 1977. At the annual meeting, however, this recommendation was not agreed upon. At a special meeting in December 1976 the quota was finally set at 33,000 t. In addition, the United States specified a fishing season from 15 August to 30 September to be conducted in a special 950 km² area with only pelagic nets or purse seines. The FRG portion of this quota equaled 4.725 t, which is approximately 5 percent of the maximum FRG catch in 1970.

What about the development of this fishery during the coming years? The last strong year class was the 1970 one. The international herring fishery has depended on this year class exclusively since 1973. About 88 percent of the FRG-caught herring in 1973, and about 73 percent of the FRG-caught herring in 1976, belonged to the 1970 year class. All other year classes were of only minor importance as shown in results of other nations, too. There are indications that no strong year classes will contribute to the stock during the next 2-3 years. As shown by results of international larval surveys and juvenile surveys prior to 1976, both the 1975 and 1976 year classes are weak, and, what is more important, the number of larvae observed in 1976 was the lowest on record in the 6-year history of the annually conducted cruises.

Since there were no worthwhile concentrations of herring to be found in the 1977 special fishing area, or "window", the international herring fishery in 1977 failed completely, based on the information and data available to date. None of the nations fishing in this area have caught herring in significant numbers. Furthermore, all of the cruises conducted by different research vessels from the United States, Canada, USSR, Poland, and FRG in the Georges Bank-Gulf of Maine area in the course of summer-fall of 1977, showed the same result. For example, the FRG research vessel *Anton Dohrn* made 78 bottom-trawl hauls (each lasting 30 minutes) in October 1977 in the Georges Bank-Nantucket Shoals area and caught a total of only 94 specimens of herring. The extent to which a spawning occurred in 1977, if any, is unknown. However, on the basis of plankton catches with special nets, there are indications that in the Nantucket Shoals area and in a narrowly encircled area on Georges Bank some spawning must have taken place. Final results of these surveys will be available in a few weeks, but more detailed information on the situation of the Georges Bank herring stock will be obtained during the annually conducted spring juvenile herring surveys which will be continued during the next few years at least. To date it is obvious that in the near future an increase in the herring catch quota for this area cannot be expected, rather the contrary will be the case. It seems out of the question that in the next 2 or 3 years that this stock will again reach a size which will allow catches at the same level as those at the end of the 1960's or at the beginning of the 1970's, provided that there is no abnormally favorable larval development or environmental setting during the next 2 or 3 years.

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MFR PAPER 1305

Economic Aspects of the Development of the Herring Roe Gillnet Fishery, Southeastern Alaska, 1976

HOWARD O. NESS

ABSTRACT—In December 1975 the State of Alaska established regulations permitting the gillnetting of herring (Clupea harengus). *Quotas were set for nine locations, totaling 975 tons. The opening at Kah Shakes Bay on 30 March continuing to the closure on 4 April 1976 was observed. Two types of gillnet operations were used. One method utilized a purse seiner as a motherboat while the other operated with a single standard salmon gillnetter. Interviews with operators provided investment and operating costs. High gross returns of the purse-seine-based operation were offset by high operating costs. The net returns to the operator were higher for the gillnet-vessel-based operation. The net returns to both groups of operators were higher than the Canadian gillnetters fishing off British Columbia. Gillnetter-based operations fished more of the nine openings than did the purse-seine-based operations. This lack of participation in additional gillnet openings by the seiners was due to coinciding dates of purse seine openings. Gillnetters consistently reported a catch more frequently than purse seiners, though the average catch size per vessel was greater for seiners. Japan receives an estimated 90 percent of the world sales of herring roe. Alaska supplied about 10 percent of the Japanese herring roe market in 1976.*

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This economic description of the herring (*Clupea harengus*) gillnet fishery in southeastern Alaska fulfills, in part, an agreement between the Alaska Department of Fish and Game and the National Marine Fisheries Service to investigate the economic worth and potential of this newly established fishery. It includes: 1) A description of the fishery, 2) descriptions of cost-earnings estimates of two gillnet methods and comparisons with earnings received by Canadian gillnet and purse seine fishermen, and 3) the marketing implications of the herring roe fishery.

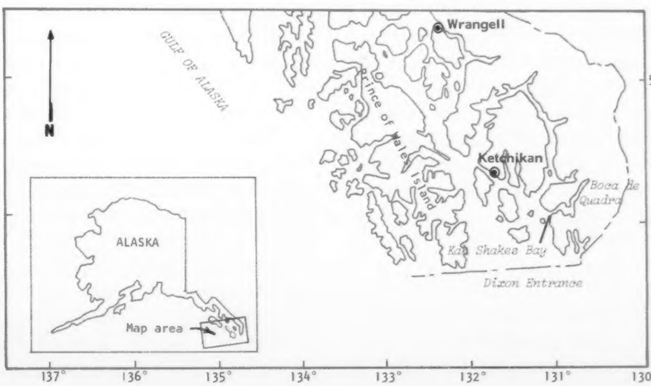
In December 1975, the Alaska Board of Fisheries permitted gillnet fishing for herring in nine widely dispersed areas within southeastern Alaska. A total of 975 tons of roe herring was allocated to the gillnet fleet in the following areas: Kah Shakes Bay, 300 tons; Helm Bay, 25 tons; Annette Island, 300 tons; Shrine Island or Berners Bay, 150 tons; Pybus Bay, 25 tons; Mud Bay, 25 tons; Gambier Bay, 25 tons; Distant Point, 25 tons; Kasaan, 100 tons.

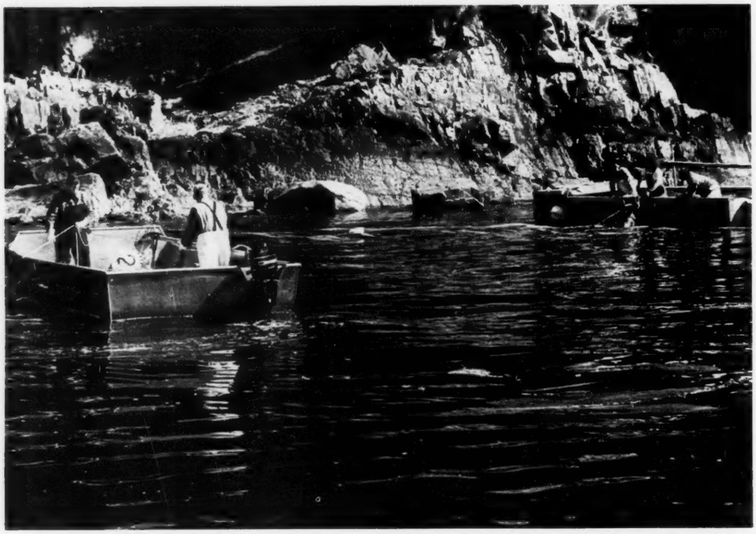
The author observed the gillnet fishery at Kah Shakes Bay during the period 30 March to 4 April 1976 (Ness, 1977).

EFFICIENCY OF INDIVIDUAL SKIFF OPERATIONS

Two basic types of gillnet operations were present: 1) One with operations based on a purse seine vessel, which uses one or more skiffs with several complements of gear and employs three

Kah Shakes Bay, near Ketchikan, Alaska.





Canadian built aluminum skiff and plywood constructed gillnet skiff built in Ketchikan, fishing side by side.

Table 1.—Total annual cost and return estimate for a herring roe gillnet operation at Kah Shakes Bay, 1976.

Item	Amt.
Costs	
Operating	
Groceries	$ 280
Fuel	400
Crew share	1,400
Total	$2,080
Depreciation	
Gillnet vessel (15 years)	$ 455
Skiff (10 years)	250
Outboard net (5 years)	200
Total	$ 905
Interest on investment	$ 350
Miscellaneous cost	$ 255
Total	$3,560
Gross revenue	$7,000
Net return to operator	$3,440

Table 2.—Comparative capital expenditures for two basic types of gillnet operations at Kah Shakes Bay, 1976.

Investments	Purse seine motherboat	Gillnet motherboat
Motherboat	$150,000	$75,000
Skiff	2,500	2,500
Outboard	700	500
Gear (net, anchor, etc.)	800	500

or more fishermen; and 2) the other was based on a gillnet vessel and supported one skiff and usually two fishermen.

The highest production for a single purse-seine-based skiff at Kah Shakes Bay was slightly more than 20 tons, which yielded gross sales of more than $6,000. The operation included the skipper and four crew members, all of whom would be involved in purse seining for herring and salmon later in the season. Individual crew shares were 10 percent of the gross receipts.

It should be noted that power net puller operations, capable of fishing more gear than (all) manual operations, are probably the most efficient and profitable. This would be particularly applicable when large concentrations of herring are present, such as occurred at the 1976 Kah Shakes Bay opening when crews had difficulty in manually pulling nets that became quickly "plugged" with herring.

COST EARNINGS ANALYSIS OF GILLNET SKIFF OPERATIONS

Skiff operators were interviewed to determine the investments and operating costs of herring gillnetting. Not enough interviews were conducted to obtain a statistically valid sample of the cost-earnings of gillnetting herring. It is believed that enough information was collected during the interviews and author's observations to derive hypothetical cost-earnings statements of the two basic types of operations. The cost-earnings information derived from interviews with individual fishermen has been modified somewhat to avoid individual identity.

Table 1 presents a cost-earnings estimate for a gillnet operation that involved a typical new gillnet vessel utilized as a base of operation and transportation. This vessel towed a skiff to three southeastern Alaskan gillnet openings and grossed slightly over $7,000. This operator reported an estimated net earning of $3,440.

Table 2 compares the initial capital expenditures of the two methods of gillnet operations. The major variation is the cost of the motherboat. The purse seiner costs twice the amount of the gillnetter. Differences in the cost of the outboards reflect the size and condition of the motor purchased. The cost of the outboards presented here are for used equipment. If new motors had been purchased, the cost would be increased. The use of more than one complement of gear by the purse-seine-based operation resulted in greater expenditures for netting, anchors, etc.

The cost-earnings data presented in Table 3 compares the profitability of two basic types of operations for one gillnet opening. The gillnet-based operation depicted in Table 3 is the same gillnet-vessel-based operation described above and summarized in Table 1.

The cost-earnings presented in Table 3 are for operation of a purse seine "motherboat" that utilized four crewmen and a limit purse seiner[1] for the operation base and tendering. The gross revenue for this operation was approximately $6,500, including $50 per ton

[1]Salmon purse seiner limited in length to 50 feet (U.S. Coast Guard registered length or 58 feet overall) by Alaska statute 16.05.835.

Table 3.—Comparative cost and return estimates for two methods of gillnet operations at Kah Shakes Bay, 1976 (purse seine motherboat and a gillnet motherboat).

Item	Purse seine motherboat	Gillnet motherboat
Costs		
Operating		
Groceries		
$10/day/person)	$ 400	$ 160
Fuel	250	300
Crew share	[1]2,600	[2]944
Total	$3,250	$1,404
Depreciation		
Motherboat (15 years)	$ 520	$ 260
Skiff (10 years)	143	143
Outboard (5 years)	80	57
Gear (5 years)	91	57
Total	$ 834	$ 517
Interest[3]		
Loan on motherboat	$ 56	$ 28
Total costs	$4,140	$1,949
Gross revenue from herring fishing	$6,500	$4,720
Net return to operator/owner	$2,360	$2,771

[1]The four crewmen on the purse seiner were paid 10 percent of the gross revenue. This share is standard payment on salmon purse seiners in southeast Alaska.
[2]The one crewman on the gillnetter was paid 20 percent of the gross revenue. This share is standard payment on gillnetters in southeast Alaska.
[3]Variation in cost between operation methods is due to differing capital outlay.

for tendering. The purse seiner's net return was less than the gillnet operator's return, $2,360 compared with $2,771. The ratio of return to capital investment of the purse seine "motherboat" operation would be considerably less than the ratio of return to capital investment for the gillnetter because the cost of a new purse seine vessel can be more than double that of a gillnetter. The additional cost of the gillnet skiff and gear is almost the same for both operations. Most skiff purchases were made in aggregate (more than one fisherman in a community purchases a skiff from a single seller). At least six skiffs in the fleet were constructed by the owner-operators. Therefore, there is not a wide variation in skiff investment.

It is evident from Table 3 that the most important profit determining factor between the two operations is the cost of labor. If the four crewmen on the purse seine operation were paid 20 percent of the gross as the single crewman on the gillnetter, it is obvious that this operator would show a loss.

HOURLY WAGE FROM HERRING FISHING

The example gillnet "motherboat" operator at Kah Shakes Bay earned $28.86 per hour for his efforts. The single crewman earned almost $10 per hour for labor. The hourly wages for the entire season for all openings compute to $20.48 for the operator and $8.30 for the crewman.

The purse-seine-based operator earned an estimated $24 per hour and the crewmen earned $6.78 per hour each at Kah Shakes Bay.

Canadian gillnet operators earned an estimated $4.25 per hour per crewman based upon 18 sixteen-hour days in 1975. The Alaska gillnetters earned more than the Canadian fishermen (at least at the Kah Shakes opening), especially considering that the Canadian calculation does not include traveling or time spent waiting on the grounds for an opening announcement.

GILLNET "MOTHERBOAT" VS PURSE SEINE "MOTHERBOAT"

Out of 42 skiff operations that fished Kah Shakes Bay, 22 also fished one or more of the other nine herring gillnet openings in southeastern Alaska in 1976[2]. Fourteen Kah Shakes Bay operators fished two additional openings. All but two of these operators fished at Helm Bay in the Ketchikan area.

Those gillnet-based operators that participated in more than one herring fishery were more successful for the gillnet season than the eight purse seine "motherboat" operators who were present at the Kah Shakes opening. At least three of these operators also participated in the Shrine Island gillnet opening. That fishery, however, was almost a total failure due to the spawned-out condition of the herring stocks.

Six purse seine "motherboat" operations, supporting at least 10 skiffs and 25 percent of the skiff effort, accounted for 15 percent of the 420-ton reported catch at Kah Shakes Bay. These same operators accounted for 13 percent of the total southeastern Alaska gillnet roe herring catch of 531 tons. The purse seiner's support operators apparently did not direct their effort toward more gillnet openings because of the coinciding herring purse seine openings in southeastern Alaska.

Mobility

Eight purse seiners fished purse seine openings in addition to supporting gillnet operations and at least 16 skiffs at Kah Shakes Bay. This is a definite advantage of the purse seining because gillnetters are restricted in their method of operation. At least 38 percent of the total gillnetting effort at Kah Shakes Bay was directed at purse seine fisheries later in the season.

Another advantage of a purse seine vessel support operation is that these "limit seiners" have the hold capacity to tender the daily catch of at least two gillnet skiffs back to the processing plant. Herring were thus worth $50 more per ton to the operators.

Advantage of Gillnetting

An advantage of gillnetting is that, assuming readily available stocks, the fishery is more reliable for the participants than purse seining. For example, at the 1976 Auke Bay purse seine fishery only 16 seiners reported landings out of 41 that fished, and the individual catch varied from just over 1 ton to 95 tons. The average was 27 tons for all the vessels that made landings and only 9 tons per vessel for the entire fleet. Seven vessels reported landings less than 27 tons. The Sitka purse seine opening was much more successful with 32 vessels reporting landings out of 41, and the vessel average was just over 24 tons for vessels that reported landings. Nonetheless, almost 25 percent of the fleet in this fishery did not make successful sets, and seven of the

[2]There were actually 42 skiffs counted at Kah Shakes Bay. Fish ticket information later indicated there were landings made on 60 individual Alaska Department of Fish and Game (ADFH) vessel numbers; this is attributable to the fact that many fishermen wish to establish a "grandfather right" in this new fishery and therefore accompanied the gillnet operations to establish a presence in the fishery. Then they indicated the ADFG number of the skiff that made the landing.

vessels that did report landings caught less than 15 tons.

At the Kah Shakes opening, all the participants of the gillnet fishery reported landings; the high skiff reported almost 20 tons and the low skiff just over 2 tons. The average landing per skiff was 10.3 tons for 42 skiffs.

Additionally, the monitoring and termination of the season when the quota has been reached is much more easily managed by the Alaska Department of Fish and Game with a gillnet fishery.

Average Gross Revenue

The average gross revenue for the 41 seiners which participated in the three purse seine openings, where a total of 425 tons of herring were landed, was $9,520. This does not compare favorably with the Canadian fishermen gross returns from herring roe fisheries. Canadian purse seiners off British Columbia averaged between $33,600 and $41,600 in the 1975 roe season for 37,500 tons of herring.

The average gross return from gillnetting in the Alaskan 1976 season was approximately $2,411, exclusive of the Annette Island opening. This was computed for an estimated 62 skiffs that took a total of 561 tons having an average value of $280/ton[3].

An interesting comparison comes to light when this average return is compared with the 1975 British Columbia Canadian gillnetters' "potential"[4] return of $3,900 to $5,250 per operation for approximatley 1,200 units. Considering that the Alaskan gillnet herring fishery is new and that inefficiencies exist, the Alaskan gillnet fleet actually did quite well during the first season when compared with the Canadian gillnetters, who have been able to develop their fishing techniques over a 5-year period.

FUTURE OF THE FISHERY

The most successful participants in the 1976 gillnet fishery were six gillnet "motherboat" operators who utilized their 25- to 33-foot gillnetters for transportation and support during the season. These vessels, accompanied by a 39-foot salmon troller, fished three or more openings and caught 313,116 pounds or 28 percent of the total catch of 1,122,392 pounds. The average gross return for each operator was just over $6,300. It would appear that these were the more successful and efficient operations and the 1977 herring roe season may witness more operations of this type.

The gillnet herring roe fishery offers an extended opportunity to earn additional income from fishing during spring when there is very little opportunity for fishing diversification. Although there is some salmon trolling and snow crab fishing activity at this time, gillnetting roe herring offers an additional fishery opportunity while requiring only a small additional investment in gear.

[3]The Auke Bay fishery landed 31 tons valued at $40/ton.

[4]Estimated by the Canadian government quota described by number of fishing units that actually fished.

MARKETING IMPLICATIONS

Herring roe, kazunoko, is a favored seafood delicacy in Japan and the salt-cured product is sold by the gram to restaurants and housewives. It is served as an hors d'oeuvre, usually during festive occasions. Herring roe remaining attached to the eviscerated cured fish is consumed in Korea and in some areas of northern Europe and the United States. The Japanese, however, account for an estimated 90 percent of the herring roe sales in the world market.

The Japanese first purchased North American roe herring in British Columbia in 1971, and approximately 5,033 metric tons of fresh, chilled, or frozen roe herring were exported to Japan that year (Table 4). British Columbia production was increased to 40,000 metric tons in 1972, 50,000 metric tons in 1973, and almost 45,000 metric tons in 1974. That same year, Japan imported 12,573 metric tons of processed herring roe; 48 percent of this came from The People's Republic of China (6,058 metric tons). Canada's production totaled 38 percent, or 4,314 metric tons of extracted roe. The United

Table 4.—Japanese herring and herring roe imports in kilograms, by country of origin, 1971-76.[1]

Product	Country of origin	1971	1972	1973	1974	1975	1976
Herring (Fresh, chilled, frozen)	China (PRC)	39,879	2,155,445	651,680	345,960	—	—
	Canada	4,478,491	2,827,866	6,398,602	2,838,307	6,428,702	4,499,883
	United States	514,177	983,424	2,438,318	1,710,922	2,427,720	996,148
	Rep. of Korea	—	1,654,498	581,924	—	—	414,250
	Sweden	—	—	97,045	—	—	—
	Denmark	—	—	540	—	—	—
	Total (incl. other countries)	5,032,538	7,621,233	10,168,109	5,688,000	8,856,422	5,910,281
Herring roe (Salted, dried, or smoked)	Rep. of Korea	79,780	584,788	1,459,408	—	975,149	1,360,039
	People's Rep. of Korea	19,992	163,418	112,101	—	6,375	14,474
	China (PRC)	111,448	3,891,568	4,781,740	6,057,505	1,115,623	1,446,620
	Iceland	1,800	—	—	—	—	—
	Norway	3,695	4,620	7,371	—	—	—
	United Kingdom	7,729	319	—	—	—	2,472
	Netherlands	980	4,000	965	—	2,856	2,440
	U.S.S.R.	16,811	—	—	—	45,377	1,552
	Canada	356,274	2,387,963	3,879,699	4,314,403	4,359,835	7,661,329
	United States	189,668	304,754	657,336	628,379	1,105,663	1,201,893
	Hong Kong	—	37,018	168,201	—	—	—
	Taiwan	—	—	7,799	—	—	—
	Poland	—	—	1,047	—	—	—
	Denmark	—	—	—	—	—	1,034
	Total (incl. other countries)	789,177	7,378,448	11,075,667	12,573,000	7,610,838	11,697,923

[1]Compiled and translated by Sunee C. Sonu, Foreign Reporting Division, National Marine Fisheries Service, NOAA, Terminal Island, Calif.

Source: Japan exports and imports, commodity by country, 1971-76. Compiled by Ministry of Finance, Japanese Tariff Association, 1977.

States only produced 5 percent of this total, or 628 metric tons. In 1975, Canadian roe fisheries yielded 60.3 thousand short tons and in 1976, the Canadians produced almost 90 thousand short tons of roe herring and supplied the Japanese market with 90 percent of its herring roe.

The Chinese, during successful fishing years, control exports of herring roe to influence the price in Japan for herring. Chinese exports of roe herring were cut back to less than 2,000 metric tons in 1976. Apparently herring production failed to materialize in the Yangtze Delta, the major Chinese herring producing area, because of the disastrous earthquake that caused mass evacuations of fishing communities along the Delta. Yangtze Delta production occurs concurrently with Canada's.

China tends to be very secretive about its herring productions. The Chinese fall and spring herring fishery board meetings are no longer held in an effort to control the flow of production information from that country. The current Chinese export policy encourages exporting to foreign nations all nonessential food items; therefore, Chinese roe herring production can be expected to be exported to Japan. Chinese consumption of roe herring is not an important market factor.

Japanese traders try to obtain as much market intelligence as they can about the amount of roe herring in cold storage in January and February and about the production prospects in North America. It is reported that false marketing information is sometimes released about the Chinese production by Japanese buyers seeking to influence roe prices in the northeast Pacific.

The California herring roe production, in January-February, although very small, is the first season to occur in North America. This is followed by the Canadian production in February-March. Alaskan roe fishery begins in southeast Alaska toward the end of March and lasts through April. It is followed by fisheries in Prince William Sound and, lastly, by Cook Inlet in April and May.

Canadian built aluminum gill net skiff, Amalga Harbor fishery, April 1977.

Plywood skiff built in Ketchikan, April 1977.

Alaska has very little marketing influence on Japan's roe herring prices. Only about 10 percent of the roe sold to Japan (around 1,100 metric tons) comes from that State. Also, a decision was made in the December 1976 Commercial Fishery Board Meeting to restrict southeastern Alaska herring fishery quota increases to include only the winter bait fishery. Increased harvests will not be allowed in the spring roe fishery.

The addition of 500 tons of herring that can be harvested in the Bering Sea by Alaskan fishermen in 1977 will have

little immediate effect on world markets. Alaska production is further disadvantaged by being last on the buying chain. If the Chinese produce and market 40-50,000 metric tons of roe herring and Canada produces 60,000 metric tons of roe herring, the herring roe market could be satisfied at around 10,000 metric tons of roe, depending upon current storage inventories in Japan. This could mean a severely depressed herring roe market in Alaska and have grave implications for that industry[5]. If this does occur, some herring roe seiners and gillnetters may wish to participate in the fall/winter fishery for bait herring after the close of the salmon seasons. A flexible management policy would be required to allow the diversification into the bait fishery, particularly if quota allocations are placed on the winter bait fishery and on roe fisheries operating on the same stocks. Japanese roe herring import quotas were enforced prior to 1972. This was initiated by the Japanese government to protect herring marketing interests of fishermen on the Japanese Island of Hokkaido. The quotas applied only to round herring and the Japanese roe industry circumvented this restriction by importing cured roe skeins, most of which were extracted in Korea. If this quota were actually enforced, it would be to the advantage of the Alaskan herring roe industry and the U.S. economy because extracted roe has more value and the increased economic activity connected with the roe extraction labor would increase economic multiplier benefits to coastal fishery communities.

[5]During low production years in China and Canada, the Alaskan herring roe industry does have an advantage because if roe production is in short supply in Japan, Alaskan processors can command a higher price for their product.

SUMMARY

Although purse-seine-based "purse seine motherboat" gillnet operators indicated the most fishing power and potential for high gross earnings, the most financially successful operations were apparently the "gillnet motherboat operators" who fished more than two openings in southeastern Alaska in 1976.

The gillnet roe herring fishery apparently has the potential to return significant gross earnings to the operator with less risk of production variability than purse seining in southeastern Alaska.

The average hourly wage to the crewmen from gillnetting roe herring was higher in southeastern Alaska in 1976 than the reported hourly wage from gillnetting roe herring in Canada in 1975.

If the People's Republic of China and Canada concurrently have peak roe herring production in any given season, the Alaskan roe market could be severely depressed because the Japanese roe markets could become totally glutted before Alaska production begins.

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More Than $10 Million Paid by Foreign Nations to Fish in U.S. 200-Mile Zone

Foreign nations paid $10 million in fees to the United States by 10 February to fish within 200 nautical miles of the U.S. coast during 1978, according to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service.

About 800 foreign vessels are expected to fish in the 200-mile zone, and total revenues are anticipated to amount to $10.1 million from the poundage fees, based on the dockside value of the fish taken, and $0.9 million from the vessel permit fees. When observers are placed aboard foreign fishing vessels, observer costs will be collected and the total will increase.

The Commerce Department agency reported that the largest total fee—$5,960,653—has been paid by Japan, permitting that nation to catch 1,157,635 metric tons (t) of fish with up to 450 vessels within the U.S. 200-mile zone. Second largest fee—$3,549,978—was paid by the Soviet Union, allocated 493,928 t with up to 200 vessels. The Japanese allocation is primarily for pollock, and the Soviet allocation primarily for pollock and hake, two species that are not sought by U.S. fishermen.

Other nations that have paid fees, the amount of catch allocated, and number of vessels already issued permits to fish, are: South Korea, $370,497, 92,598 t, 18 vessels; Spain, $266,347, 18,156 t, 30 vessels; and Italy, $78,978, 4,125 t, 15 vessels.

Permits were to be issued to Bulgaria, which has paid $16,513, 1,504 t, 3 vessels; to Mexico, $155,070, 10,528 t, 14 vessels; and to Taiwan, $26,094, 5,822 t, 8 vessels. Applications approved but not ready for permit issuance were from Poland, $162,262, 22,622 t, 22 vessels; and Cuba, $112,183, 9,715 t, 17 vessels. France and the Federal Republic of Germany (West) were also expected to apply for permits to fish.

NOAA Names New Deputy, Associate Administrators

Paul L. Leventhal and James P. Walsh have been selected to be Assistant Administrator for Policy and Planning and Deputy Administrator, respectively, of the National Oceanic and Atmospheric Administration, the Commerce Department agency has announced. Leventhal is a former journalist and special counsel to the Senate Government Operations Committee while Walsh, for the past year, was general counsel of the Senate Committee on Commerce, Science, and Transportation.

Leventhal assumed the new position as part of a reorganization of the Commerce Department agency by NOAA Administrator Richard A. Frank. The reorganization is designed to equip NOAA to meet new responsibilities which Congress has entrusted to NOAA over the recent past, such as ocean use and resource management, and climate and weather modification.

During much of 1977, Leventhal, under a Ford Foundation grant, wrote a book on nuclear proliferation which will be published this spring by Random House. In connection with the book, he was a research fellow at the Harvard Program for Science and International Affairs, with guest privileges at the Brookings Institution.

Leventhal was special counsel for the Senate Government Operations Committee from 1972 through 1976. His responsibilities included the reorganization of atomic energy and governmental enforcement functions within the Executive Branch and the study of Federal science policy and research and development activities.

From 1969 to 1972 he was press secretary to New York Senator Jacob K. Javits, and also served as campaign press secretary to New York Senator Charles E. Goodell in 1970.

A former journalist, Leventhal was Congressional correspondent for the National Journal in 1972. From 1961 to 1968, he did political and investigative reporting for Newsday, the New York Post, and the Cleveland Plain Dealer.

A native of New York City, Leventhal received a bachelor's degree, magna cum laude, in 1959 from Franklin and Marshall College, Lancaster, Pa., and a master's degree from New York's Columbia University Graduate School of Journalism in 1970. Leventhal, his wife Sharon, and their two sons live in Chevy Chase, Md.

Walsh, a native of Coos Bay, Ore., was director of the Senate's National Ocean Policy Study during 1977 in addition to his Senate committee duties. Richard A. Frank, NOAA Administrator, said that Walsh's knowledge and experience in ocean affairs, as well as his understanding of NOAA's atmospheric missions, will be a welcome addition to NOAA's management team.

From 1972 until last April, the Stanford University graduate served as staff counsel to the Senate Commerce Committee and counsel to the Senate Ocean Policy Study. In those posts he had responsibility for all ocean-related legislative programs, merchant marine, ocean pollution, coastal zone management, and other related subject areas.

Walsh received his J.D. and LL.M. degrees from the University of Washington in 1970 and 1971, respectively, and until June 1972 was Assistant Attorney General for the State of Washington, including service as counsel to the State's Oceanographic Commission.

He is a member of the Law of the Sea

Advisory Committee at the State Department, as well as the Washington and District of Columbia Bar Associations and the American Society for International Law. Walsh, his wife, and two children live in Washington, D.C.

Foreign Fishing Vessels Off U.S. Coastlines Decrease in November

The 256 foreign fishing and fishing support vessels sighted during November 1977 within the U.S. 200-mile conservation zone continued a 5-month decline from the year's high of 767 sighted in June, and were 122 fewer than those identified in October, according to preliminary figures released by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, a Commerce Department agency.

The decrease is due primarily to the closure of the Pacific hake fishery, with normal seasonal decline in fishing activities and reduction in the number of foreign vessels permitted to fish within the 200-mile zone also contributing.

The foreign vessels, from eight nations, were sighted off the coasts of New England and the mid-Atlantic States and Alaska. The largest number, 142, was from Japan, which had 126 vessels fishing for groundfish and pollock off Alaska, and 16 fishing for squid off New England and mid-Atlantic. The Soviet Union had 49 vessels fishing for groundfish in Alaskan waters.

The summary of foreign fishing vessels operating off U.S. coasts during November 1977 and November 1976 is listed here in tabular form.

Foreign vessels sighted off the coasts in 1976 were as follows: January-420, February-510, March-435, April-560, May-924, June-970, July-842, August-543, September-514, October-452, November-258, December-240. In 1977: January-319, February-314, March-180, April-235, May-374, June-767, July-786, August-492, September-437, October-378, and November-256.

The November sightings were made by representatives of the National Marine Fisheries Service and by personnel of the U.S. Coast Guard, conducting joint fisheries enforcement patrols from Coast Guard aircraft and cutters.

Area	Nation	No. of vessels Nov. 1977	Nov. 1976
New England, mid-Atlantic	E. Germany	9	1
	Soviet Union	0	8
	Poland	0	11
	Spain	30	11
	Japan	16	9
	Italy	7	10
	Bulgaria	0	1
	S. Korea	0	4
		62	55
West Coast	Panama	0	5
	Soviet Union	0	1
	S. Korea	0	9
	Bulgaria	0	5
	E. Germany	0	8
	Taiwan	0	1
		0	29
Alaska	Japan	126	89
	S. Korea	16	3
	Taiwan	1	2
	Soviet Union	49	80
	Poland	2	0
		194	174
	Total	256	258

Pharmaceutical Waste Dumping Eyed in Gulf

A study of the environmental effects of dumping pharmaceutical wastes at a site about 40 miles north of Arecibo, Puerto Rico, was started in February by three universities under $350,000 in grants from the National Oceanic and Atmospheric Administration (NOAA).

P. Kilho Park, Manager of NOAA's National Ocean Survey (NOS) Ocean Dumping Program, said the biological effects, chemical fates, and dispersement of about one million gallons of waste was to be studied. Onsite activities concentrated on dispersion of waste plumes, while laboratory work focused on the specific effects of the wastes on different types of marine organisms including fish and other marine life.

The wastes, shipped by barge from Puerto Rico, included organic solvents and the remains of antibiotics production such as penicillin. After being dumped, they were tracked by the research vessel *Knorr* of Woods Hole Oceanographic Institution, and by a NASA aircraft from the Langley Research Center.

Universities receiving grants for the monitoring program from the Commerce Department agency are Texas A&M University, College Station, Tex. ($230,000); the Marine Science Institute of the University of Texas, Port Aransas, Tex. ($105,001); and, Johns Hopkins University's Chesapeake Bay Institute, Baltimore, Md. ($42,000).

The scientific party was directed by Michael Devine and Edward R. Meyer of the Ocean Dumping Program, and included scientists from the Chemistry and Oceanography Departments at Texas A&M, and NOAA's Atlantic Oceanographic and Meteorological Laboratories in Miami, Fla.

BILLFISH, SHARK RULES PROPOSED

Proposed regulations to prevent the retention of billfishes and to control the tonnage of sharks that may be caught by foreign fishermen off the Atlantic Ocean and Gulf of Mexico coasts have been published by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service. The regulations implement a Preliminary Fishery Management Plan prepared by the Commerce Department agency. The preliminary plan will remain in effect until final plans for these species are developed by the appropriate Fishery Management Councils.

Under the regulations, which were expected to become effective in late February, foreign fishermen will be required to release any blue marlin, longbill spearfish, sailfish, swordfish, or white marlin caught within the U.S. 200-mile fishery conservation zone. These fish often are caught on longline gear being used for tuna, a species not under the jurisdiction of the Fishery Conservation and Management Act of 1976. The floating longlines, sometimes 50 or more miles long, are rigged with thousands of baited hooks.

The proposed regulations require foreign fishermen to obtain permits if

they are using gear that may catch billfishes and sharks. If billfish are caught, they must be released by cutting the leader to the hooks or by other means without removing the fish from the water, regardless of their condition. In addition, the foreign ships must file weekly reports on, among other things, the numbers and types of billfish caught and released. An annual report also must be submitted.

A total catch of not more than 1,150 metric tons of sharks, excluding dogfish sharks, is established by the proposed regulations. When the limit has been caught, the same restrictions as to billfishes will apply to all sharks caught on longlines.

Marine "Rafts" Show Promise in Luring Fish

The National Oceanic and Atmospheric Administration (NOAA) *RV Townsend Cromwell* returned to Honolulu on 17 December after a 30-day cruise off of Palmyra Island to study the effectiveness of artificial drift objects to attract schools of fish, particularly tuna. Results were called "encouraging."

"Tunas, particularly the skipjack and small yellowfin, are known to be attracted to drifting logs and other objects. In the western Pacific where such objects are plentiful, Japanese tuna fishermen regularly fish around these logs, and even tie up to one at night so that they may fish around it the next morning," says Richard Shomura, Director of the Honolulu Laboratory of the NMFS's Southwest Fisheries Center.

Walter M. Matsumoto, Chief Scientist of the cruise, reported that a series of rafts, spaced about 1 mile apart and connected by a line 5 miles long, was set adrift 285 miles northwest of Palmyra Island and followed for 16 days. Each raft measured 4 feet × 12 feet and had a 2-foot strip of rope netting either 50 or 100 feet long suspended from it to simulate a log floating vertically in the water. The rafts were monitored daily for accumulation of fish under them, and an area of up to 6 miles from the rafts was scouted for bird flocks and fish schools. Matsumoto noted that on the open ocean the appearance of bird flocks usually indicates the presence of fish schools.

Two bird flocks appeared in the vicinity of the rafts on the third day and a total of 17 bird flocks were seen from the third through the eleventh days. None were seen in the last 5 days due to poor visibility caused by bad weather. Two of the bird flocks were pursued and the chase led to two fish schools, one of skipjack tuna, the other of skipjack tuna and small yellowfin tuna. All fish schools and bird flocks except one were seen within 3 miles of the rafts, suggesting that the rafts may have been effective in attracting the schools. On the basis of these encouraging results, similar cruises will be made in the future.

This raft, 3 feet wide × 12 feet long, is made of 2-inch × 6-inch lumber. Netting, 12-foot × 45-foot fine mesh (1-inch stretch mesh), is hung from one end of the raft. Buoys (not shown) have two 55-gallon drums as the main flotation units. Netting, 45 feet long, made of ⅝-inch polypropylene rope was hung from them.

This study was one of several conducted by the NMFS's Honolulu Laboratory to help commercial fishermen increase their tuna catches. It was done in cooperation with the Pacific Tuna Development Foundation.

FISH MEAL, OIL SUPPLIES TOLD

Supplies of fish meal and fish oil in domestic and international trade declined during the first half of 1977 from a year earlier, while the supplies of fish solubles increased, according to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, a Commerce Department agency.

Fish meal and fish solubles are nutritionally important ingredients in some manufactured animal feeds, especially feed for poultry and farmed fish, trout and catfish. In the United States, fish oils are used as ingredients only in inedible products, like paints, varnishes, resins, plastics, and lubricants.

Fish meal, oil, and solubles are produced from many species of fish, including menhaden, anchovy, herring, pilchard, and capelin, most of which are not eaten by humans. Total production of fish meal, 100,005 short tons, fell by one percent during January-June 1977, despite a 10 percent rise in menhaden production. Menhaden solubles helped raise the total production of fish solubles by 3 percent to 44,818 short tons. The oil yield of menhaden landings, however, fell substantially, reducing total U.S. production of fish oil by 18 percent, to 52 million pounds.

Production of fish meal by member countries of the Fishmeal Exporters Organization, excluding Angola, fell 21 percent during January-May 1977.

Nevertheless, exports from those countries rose, as high inventories at the beginning of the year were drawn down rapidly. Peru accounted for most of the decrease in fish meal production, most of the increase in exports, and most of the inventory reduction.

Imports of fish meal by the United States fell by 6 percent during the first half of 1977 from a year earlier to 53,777 short tons, mainly because of the decline in receipts from Peru, down about 11,000 short tons, and from Canada, down about 5,000 short tons. These declines were partially offset by the increase in receipts of almost 13,000 short tons from Norway and other countries.

The reduction in both U.S. imports and exports of fish meal and fish oil indicates tighter domestic and international supply situations. While the United States is a net importer of fish meal, it is a net exporter of fish oil. In the first half of 1977, U.S. fish oil exports were at the lowest level since 1968.

Ultraviolet Rays Affect Shrimp Growth, Survival

Some shrimp near Seattle, Wash., are getting sunburns, as part of a study to determine the effects that thinning of the atmospheric ozone layer might have on terrestrial and aquatic life.

"Scientists as well as the public are increasingly concerned that pollutants in the upper atmosphere may deteriorate the protective ozone layer and therefore allow dangerous ultraviolet radiation to reach the earth's surface," David Damkaer of the National Oceanic and Atmospheric Administration said. "But there is very little information on the effects of ultraviolet radiation on living creatures, particularly its effects on marine life."

With funds from the Environmental Protection Agency, Damkaer is studying the effects of varying levels of ultraviolet radiation on zooplankton—tiny drifting animals—that live in the upper layers of the sea. So far, the scientist and his colleagues at NOAA's Pacific Marine Environmental Laboratory (one of the Commerce Department agency's Environmental Research Laboratories) have found that ultraviolet radiation can have dramatic, even lethal, effects.

Though seawater filters out much ultraviolet radiation from the sun, Damkaer explained, in clear coastal waters some 10 percent of this radiation striking the sea surface can still penetrate to a depth of about 30 feet (10 m). Many species of zooplankton, including the larvae of commercially important species of shrimp, crab, oysters, and mussels, live entirely in this upper 30 feet.

In the Manchester Aquaculture Laboratory of NOAA's National Marine Fisheries Service, across Puget Sound from Seattle, Damkaer is exposing a wide variety of species to differing doses of ultraviolet radiation. He notes how their behavior, growth rate, and survival are related to the amount of ultraviolet, length of exposure, and wavelength of radiation, paying particular attention to commercial species and species known to be critical elements of the ecosystem. The experimental zooplankton are kept in seawater taken directly from the Sound, and are illuminated by sunlamps with filters to vary the intensity.

Experiments so far have been conducted on three commercial shrimp species, with dramatic preliminary results, according to Damkaer. Newly hatched shrimp larvae were exposed to white light and to ultraviolet radiation for 3 hours a day. After 12 days, 74 percent of the larvae that were exposed only to white light were still alive; fewer than 18 percent had survived the ultraviolet treatments. Furthermore, Damkaer said, the development of the shrimp exposed to ultraviolet was retarded.

Although it has not yet been possible to determine exact subsurface ultraviolet light levels, Damkaer speculates that shrimp larvae may already be living near their tolerance limit for ultraviolet, and that a slight increase could be damaging. In fact, plankton life cycles may be timed to seasonal changes in ultraviolet radiation from the sun. Zoologists have wondered why the breeding period for shrimp is not at times when food is most abundant. The difference may be due to ultraviolet levels. "Perhaps their late winter, early spring, breeding period has evolved to coincide with a period of low ultraviolet levels and fair food supply," Damkaer suggested. "Perhaps poorly understood fluctuations in some plankton populations parallel fluctuations in ultraviolet radiation."

The NOAA scientists are now focusing on the larvae of crabs, who seem to have a greater tolerance to ultraviolet, according to Damkaer. This study is still in its preliminary stages.

Food Fish Market Review Reported

Canned salmon consumption in the first half of 1977 was 50 percent above the first half of 1976 as prices of major fishery products hit record levels, according to an economic analysis by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service. The Commerce Department agency report said supplies of tuna were restricted, resulting in increased prices and fewer sales, because the U.S. tuna fleet remained in port for about 2 months.

Salmon exports doubled, principally because Japan's heavy buying of fresh and frozen salmon, but continued above-average production of canned salmon in the remainder of 1977 was expected to sustain supplies and consumption at the previous year's level. Higher prices for major fishery products have caused increased price competition with meat and poultry and may have begun to affect sales of some finfish products, the analysis said.

Movement of sticks and portions and cod and flatfish fillets was practically unchanged, while sales of ocean perch fillets declined because of lower

supplies. Consumption of canned sardines was relatively unchanged.

Wholesale prices for fish sticks and portions increased 25 percent over 1976; cod fillet prices were up one-third; other fillet prices increased 5-8 percent. Canned tuna prices were 16-20 percent higher. Canned salmon prices were mixed; red salmon prices were higher, but canned pink and chum salmon prices were lower.

New supplies in the first half of 1977 were aided by record imports of fish blocks, an 18 percent increase in imports of canned sardines, a similar increase in raw tuna imports, and a 38 percent rise in groundfish landings. However, substantially lower imports of flounder, turbot, ocean perch, and halibut restrained supplies.

New supplies of finfish products will be limited by seasonally low landings, quotas restricting catches here and abroad, and strong overseas markets that may draw supplies away from the United States.

Supplies of finfish products should continue to meet quantities demanded, except that block, fillet, and halibut supplies are expected to tighten in the early months of 1978.

Demand was expected to remain good, except for some weaknesses in demand for sticks, cod fillets, halibut, and canned tuna. There may be increased resistance to record finfish prices, and increased competition from relatively lower meat and poultry prices, appearing to steady finfish prices.

Fishing Violations by U.S. Fishermen Reported

During 1977 there were more than 170 alleged violations of regulations governing the catch of cod, haddock, and yellowtail flounder by U.S. commercial fishermen in the New England area, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service has announced. Approximately 90 vessels were involved.

Under the regulations, a violation may result in a maximum administrative fine of $25,000, suspension or revocation of the license, or forfeiture of the catch and vessel. Mitigating circumstances may lead to recommendation of a lower penalty or downgrading of the violation to a citation, usually issued for minor infractions and not carrying a penalty. There were approximately 115 citations issued during 1977. Most of the alleged violations occurred when fishermen caught more fish per trip than authorized by regulations.

Proposed fines have ranged between $500 and $25,000 for each violation, depending upon the extent by which the authorized catch limits were exceeded. The average proposed fine for U.S. fishermen who exceeded the limits by 10-25 percent is about $2,800; by 26-100 percent, about $7,300; and by more than 100 percent, about $21,000.

It is estimated that more than 1.3 million pounds of cod, haddock, and yellowtail flounder have been landed by domestic fishermen in excess of the quotas of about 132 million pounds established by the regulations.

All fishermen have been notified of alleged violations pending against them for 1977. Following review by National Marine Fisheries Service headquarters, Notices of Violation are sent to the fishermen, telling them of the alleged infraction and the amount of the proposed administrative fine. They have 45 days to pay the fine or request a hearing.

The regulations, issued by the Secretary of Commerce, were implemented to enforce the Fishery Management Plan for Groundfish as developed by the New England Fishery Management Council and approved by the Secretary.

Winter of 1976-77 Chilled Gulf Stream to Unusual Depth

The severe winter of 1976-77 in the eastern United States caused the Gulf Stream system to give off unusually large quantities of heat to the atmosphere, according to a report by a National Oceanic and Atmospheric Administration (NOAA) oceanographer.

The Gulf Stream carries heat as well as water, and helps regulate the planet's temperature. In winter, the stream transports enormous quantities of water-borne heat energy northward, and yields up large amounts of this energy to the cold winter atmosphere. In 1976-77, the Gulf Stream system seems to have given up more heat than usual, leaving the northwestern Sargasso Sea chilled to depths as much as 100 m (300 feet) deeper than in more moderate years.

"The main surprise here is that a single severe winter could so disrupt recent warming trends," according to Ants Leetmaa, an oceanographer with NOAA's Atlantic Oceanographic and Meteorological Laboratories in Miami, Fla. In a recent issue of *Science*, Leetmaa described an exploratory cruise aboard NOAA's *Researcher* to the northwestern Sargasso Sea last spring, to observe the effects of the record-breaking winter. The area surveyed was roughly between long. 67° and 73°W, and lat. 32° and 38°N. Instruments that sense temperature, salinity, dissolved oxygen, and other physical properties of the sea were used in the investigation.

Ordinarily, seasonal cooling in this area in winter creates a "pool" of water with temperatures of about 64°F (18°C), with a well-mixed layer extending from the surface to about 1,000 feet (350 m), according to Leetmaa. The main thermocline—a layer where water temperature and density change sharply—occurs under this very stable layer of so-called "18-degree water." Thus, Leetmaa wrote, vertical shifts of the thermocline indicate changes in the volume of the pool of 18° water—and the extent to which the ocean has been cooled by the atmosphere.

Leetmaa found the thermocline south of the Gulf Stream had descended significantly after last winter. In the southwestern area, he detected the thermocline at slightly more than 2,400 feet (800 m), the deepest level discovered on the expedition. In more moderate years, he reported, this thermal boundary lies between 1,800 and 2,100 feet (600 and 700 m).

"It is very difficult to cool ocean

water to great depths by even half a degree, and push the thermocline down a hundred meters," Leetmaa wrote. "Enormous quantities of heat must be removed from the water column to change water temperature at all, and the deeper the cooling extends, the more heat has to be lost. For example, a half-degree temperature change in a column of water 500 m deep takes five times the heat loss of reducing the temperature by a half degree in a column 100 meters deep.

"Most winters don't have much effect on the volume—or temperature—of the persistent pool of 18° water. But another winter like the last one could cool it down more, increasing the pool's volume and pushing the thermocline still deeper."

While the processes that create the persistent pool of 18° water in the Sargasso Sea are not well understood, Leetmaa noted that they may play a role in regulating global climate. "Some scientists," he said, "believe that the Gulf Stream system is partly sustained by the processes that create this relatively cold pool of water." That possibility will be explored in further studies by the Commerce Department researchers.

Charter Boat Owners Can Delay Taxes for Construction, Repair

Charter fishing boat owners can delay paying Federal taxes on income from their vessels and use the funds to construct new, or reconstruct used, vessels, under a new ruling adopted by the National Marine Fisheries Service's Fishing Vessel Capital Construction Fund program.

Under the regulation change made by the Commerce Department agency, a vessel is now qualified for the program if it is documented by the Coast Guard to operate in both the fisheries and the coastwise trade. Previously, only vessels documented solely in the fisheries trade were qualified. An additional qualifying factor for charter fishing vessels is that they be certified by the U.S. Coast Guard to carry more than six passengers. This requirement can be overcome by providing proof that the vessel is used for commercial purposes.

The Capital Construction Fund program allows fishing vessel owners to keep Federal taxes they otherwise would pay on income from the operation of their vessels, provided the taxable income involved is reserved for the construction of new vessels, or the reconstruction of used ones. The taxes deferred eventually are repaid to the government through a reduction in the future depreciation allowed on vessels constructed or reconstructed under the program.

Charter fishing vessels also are qualified for another NMFS vessel assistance program, the Fishing Vessel Obligation Guarantee Program. Again, dual documentation is required and the six-passenger certification applies. Up to 15-year financing at reasonable interest rates is available under the Fishing Vessel Obligation Guarantee Program for the debt portion of vessel construction, reconstruction, or reconditioning costs. The 15-year ceiling on debt maturity would be increased to 20 years under a proposal now being considered.

Interim Policy Proposed on FCZ Joint Ventures

Foreign vessels within the 200-mile Fishery Conservation and Management Zone may be permitted to buy or receive fish caught by U.S. fishermen, under an interim policy proposed by the National Oceanic and Atmospheric Administration (NOAA) in February. Vessel owners wishing to participate in such so-called "joint ventures" with U.S. fishermen would be required to obtain permits issued under Preliminary Management Plans.

The permits would be issued by the Secretary of Commerce after it was determined that the fish to be sold or delivered by domestic fishermen exceeded amounts U.S. processors were capable of, and intend to, process. In addition, the amounts of fish caught by American fishermen could not exceed the limits established to insure a continued growth of the stocks. The foreign vessel applying for the permit also must have demonstrated the capability to process the American catch.

Several other factors would also be considered in issuing a permit: the potential for gear conflicts between U.S. vessels, the impact on U.S. consumers, prices at all levels, and the impact on employment in the fishing industry and on the income of domestic fishermen, processors, and industry workers.

Under the proposed interim policy, foreign countries would have to inform the State Department of the amounts of each species of fish they would obtain from U.S. fishermen, in addition to information normally furnished for a permit to fish within the 200-mile conservation zone.

The relevant Regional Fishery Management Council would obtain public comment on the applications, and would recommend to the Secretary of Commerce approval or disapproval, indicating any terms and conditions that should be contained in the permit. This recommendation would be reviewed with the Secretary of State and the Coast Guard, and approval or disapproval would follow. If the application were approved, it would be issued to the foreign country with any conditions and restrictions the Secretary deemed necessary.

Each application would be considered individually, and a permit would be valid only for the calendar year in which is was issued. Any permits issued would not set a precedent for permits requested in later years.

The proposed interim policy appeared in the Federal Register on February 8. A final policy is expected to be developed late this year. Prior to adoption it will be published and the public given an opportunity to comment on it.

Argentina Seizes Nine Soviet and Bulgarian Trawlers

The Argentine Navy seized seven Soviet and two Bulgarian stern factory trawlers fishing in Argentine-claimed waters last September and October. The seizures followed press reports in mid-September 1977 of unidentified foreign vessels—reports which were based on alleged sightings of such vessels by Argentine fishermen and merchant seamen. It is believed that as many as 30 foreign vessels, most of them Soviet, had been operating for at least 6 weeks prior to the September seizures along the Argentine coast within the 200-mile territorial sea.

VESSELS SEIZED

Three Argentine destroyers, the *Rosales, Segui,* and *Py,* began operations against the foreign fishing vessels in the afternoon of 21 September 1977. The Argentine naval vessels found nine Soviet vessels fishing approximately 130 miles east of Cabo Dos Bahias (Fig. 1). The vessels had been located by the Argentine Naval Air Force. The destroyers signaled the Soviet vessels to stop and fired warning shots when the Soviet fishermen refused to do so. Argentine naval authorities report that the first warning shots were fired at a distance of 600 m, but that the Soviet vessels did not stop until the range was reduced to 20 m. Five Soviet trawlers managed to escape; the remaining four, *Bussol, Apatit, Teodor Nette,* and *Magnit,* were seized.

The Soviet masters refused to aid the Argentine prize crews in boarding their vessels and the Argentine sailors had difficulty boarding in the rough seas. Once on board the Soviet trawlers, the sailors were at first refused food and then given meals which Argentine press reports characterized as "inedible".

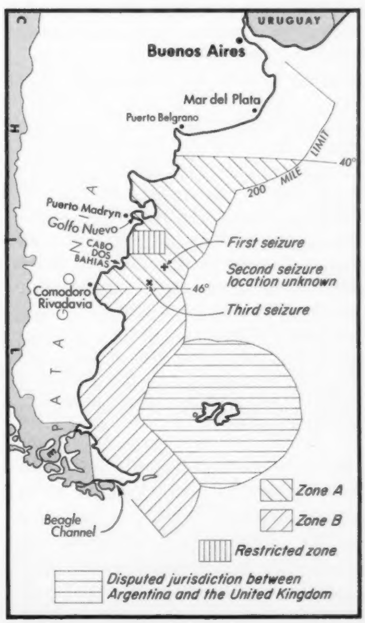
The four Soviet trawlers were escorted to Puerto Madryn, about 700 miles south of Buenos Aires, and arrived there on 22 September. The Soviet masters refused to bring their vessels into port and instead anchored them in Golfo Nuevo.

The Argentine Government submitted a formal protest to the Soviet Chargè d'Affairs in Buenos Aires, Genadii I. Sazhenev, on 23 September, stressing Argentina's surprise and annoyance at the activities of the Soviet fishing fleet. The note pointed out that Soviet fishermen violated Argentine sovereignty and its fishing regulations, both of which were previously made known to the Soviet Government. Later that same day, the Soviet Consul Constantin Verniskiy met with Argentine authorities in Puerto Madryn, and persuaded the Soviet masters to cooperate with local Argentine officials. The masters then made statements to the Argentine authorities in the presence of the Soviet Consul.

A fifth Soviet vessel, the *Nerey,* was seized by the Argentine destroyer *Ara Rosales* on 26 September. The following day the Argentine Foreign Ministry summoned Sazhenev again and gave him a second protest note. Despite these protests, the Soviet and Bulgarian vessels continued to fish in Argentine-claimed waters. On 1 October, the Argentine naval vessels *General Belgrano, Segui, Piedrabuena,* and *Py* seized another four stern factory trawlers (two Soviet and two Bulgarian reportedly 170 miles east of the Argentine port of Comodoro Rivadavia[1], somewhat to the south of where the first four Soviet vessels were seized. The Argentine Navy fired at the two Bulgarian vessels, the *Aurelia* and the *Ofelia,* when they refused orders to stop. The *Aurelia* was hit three times and it is believed that one crew member was killed and several others wounded. During the boarding, a small boat overturned and three Argentine sailors drowned. The *Ofelia* and the two Soviet trawlers, the *Franz Hals* and the *Prokopevsk,* arrived in Puerto Madryn on 2 October escorted by the Argentine Navy. The *Aurelia* was so badly damaged that it had to be towed to Puerto Madryn by the Argentine vessel *Gurruchaga.*

As a result of these incidents, a third protest note was delivered to the Soviet Embassy and a note was also delivered to the Bulgarian Embassy. The first secretaries of the Soviet and Bulgarian Embassies in Buenos Aires traveled to Puerto Madryn on 2 October to review the statements made by the masters and other officers of the four newly seized fishing vessels. On 4 October, accompanied by Argentine fishery officials, the two diplomats boarded the trawlers to inspect their catch.

Figure 1.—Argentina's foreign fishing zones, 1977.



[1]Bulgarian and Soviet news releases maintain that their vessels were seized more than 20 miles beyond the Argentine 200-mile zone.

The Bulgarian stern trawler *Ofelia,* when seized in 1976 for violation of the U.S. Contiguous Fishery Zone. In background are two Polish stern trawlers and a U.S. Coast Guard helicopter. See "Bulgarian Stern Trawler Seized off Oregon," Mar. Fish. Rev. 39(3):33.

Table 1.—Fishery commodities aboard Argentine-seized Soviet vessels, 1977.

	Fishery commodities (t)	
Vessel	Frozen fish[1]	Fish meal
Apatit	722	70
Bussol	800	—
Magnit	450	15
Teodor Nette	280	—
Total	2,252	85

[1]Primarily frozen hake.
Source: Buenos Aires Radio, 24 September 1977.

Table 2.—Soviet catch in the southwest Atlantic, 1965-75.

Year	Catch (1,000 t)	Year	Catch (1,000 t)
1965	—	1971	26.2
1966	73.3	1972	4.6
1967	677.7	1973	6.1
1968	189.8	1974	12.9
1969	92.9	1975	8.9
1970	420.6	1976	n.a.

Sources:
TsNIITEIRKh, Moscow 1971, for 1965-70 and FAO, "Yearbook of Fisheries Statistics" for 1971-75.

The operations against the foreign trawlers were personally directed from a Buenos Aires command post by the Argentine Naval Commander and a member of the ruling military junta, Admiral Emilio Massera Padula. He issued the following communique on 2 October:

> "I wish to congratulate the Navy Operations Command and, through it, subordinate commands and boarding parties, for their efficiency, swiftness and diligence in carrying out orders given for the defense of Argentine sovereignty and sea. The actions which were carried out decisively illustrate the unyielding determination of the Argentine Armed Forces to preserve to the ultimate consequences the integrity of the national heritage. The loss of sailors during this operation is new and painful testimony to the Argentine people that the security of the maritime fatherland is in the hands of Argentines who are willing to reassert, with their lives and through their actions, the unyielding defense of the Republic."

In a military ceremony at Puerto Belgrano, Argentina's major naval base, Admiral Massera further stated: "We will take similar actions as we did before against any intruder, under any flag, and on any grounds."

Argentine authorities confiscated the catch of the seized vessels. The Spanish company Empressa Bajamar S.A. based in Barcelona bought the catch of the five Soviet trawlers at an auction and was to ship most of it to Spain aboard a Soviet refrigerated transport vessel. Initial reports had indicated that the Argentines wanted to sell the confiscated catch back to the Soviets owing to the limited cold storage capacity in Puerto Madryn. The disposition of the catch of the remaining two Soviet trawlers and the two damaged Bulgarian trawlers was unknown.

After unloadng their catch, the Soviet trawlers were allowed to leave Puerto Madryn. The trawlers were resupplied by a Soviet vessel on 3 November. The first Soviet vessel to be released was the *Nerey* which sailed on 9 November. The last of the seven seized Soviet trawlers, the *Franz Hals,* was allowed to leave on 23 November. The two Bulgarian trawlers were allowed to leave Puerto Madryn on 1 December after undergoing repairs. Argentine law reportedly provides for fines of as much as $100,000, but no information is currently available on the amounts of the fines, if any, which were levied against the seized vessels.

Press reports indicated that Argentina conducted extensive naval exercises in early November. The exercises were carried out in Golfo Nuevo close to where the Soviet and Bulgarian vessels were being held.

VESSELS AND CATCHES

The four Soviet trawlers seized on 21 September held 2,252 metric tons (t) of frozen fish, primarily hake[2], and 85 t of fish meal (Table 1). Each vessel had a crew of about 100, including 9 women. The quantity of fish and/or fish meal confiscated from the other five Soviet and Bulgarian trawlers is not yet known. Whatever the total amount, however, the known quantity of frozen fish seized from the first four Soviet vessels is a significant percentage of the total Soviet catch in the southwest Atlantic in recent years (Table 2).

The general specifications of the captured vessels are given in Table 3. Most of the Soviet vessels are of the *Skryplev* and the related *Rembrant* classes. The *Skryplev*-class vessels were constructed in Denmark during the 1960's and early 1970's. The *Franz Hals* (*Rembrant* class) was constructed in the Netherlands in the early 1970's and its design is basically the same as that of the *Skryplev* class. The *Nerey* is one of a

[2]Patagonian hake, *Merluccius hubbsi.*

Table 3.—Specifications of seized Soviet and Bulgarian vessels.

Name	Country	Class	GRT	Length (m)	Beam (m)	Speed *Knots*	Cargo capacity (t)
Apatit	USSR	Skryplev	4,700	103	16	14	1,700
Bussol	USSR	Skryplev	4,700	103	16	14	1,700
Franz Hals	USSR	Rembrant	4,700	103	16	14	1,700
Magnit	USSR	Skryplev	4,700	103	16	14	1,700
Nerey	USSR	Atlantik III	3,930	102	15	15	1,000
Prokopevsk	USSR	Skryplev	4,700	103	16	14	1,700
Teodor Nette	USSR	Mayakovskiy	3,170	85	14	14	900
Aurelia	Bulgaria	B-418 (II)	2,470	89	15	15	3,990[1]
Ofelia	Bulgaria	B-418 (II)	2,470	89	15	15	3,990[1]

[1]Not available in metric tons, figures are in cubic meters.
Source: Files of the Branch of International Fisheries Analysis, NMFS, NOAA.

series of *Atlantik III* class vessels constructed in the German Democratic Republic within the last decade. The other Soviet vessel, the *Teodor Nette*, is Soviet-built and belongs to the *Mayakovskiy* class. The two Bulgarian vessels, the *Aurelia* and the *Ofelia*, are Polish-built B-418(II)-class trawlers.

SOVIET FISHING IN THE SOUTHWEST ATLANTIC

The expansion of Soviet fishing into the southwest Atlantic had its beginnings in 1962 when the Soviet Ministry of Fisheries secured a fishing base in Cuba. During the next 3 years, the Soviet Union assisted Cuba in the construction of a large, modern fishing port in Havana. Once it was completed, the Soviet Union was logistically able to expand its fishing southward into the waters of the Patagonian Shelf, where large, unexploited fishery resources were available.

The Soviet Union began to fish off Argentina in the summer of 1966 and during that first year caught 73,300 t, mainly Patagonian hake. In 1966, Argentina had only a 3-mile territorial sea and the Soviets could fish in a large area without restrictions. According to Argentine press reports, more than 200 Soviet trawlers were sighted off Argentina and Uruguay in 1966.

The presence of Soviet fishing vessels off their coast angered many Argentines. One reason was that Soviet vessels often did not respect Argentina's 3-mile territorial limit. Soviet violations eventually became so numerous that in December 1966 the Argentine Foreign Ministry made a formal protest to the Soviet Ambassador concerning Soviet fishing in Argentine waters. At the same time informed sources let it be known that Argentina was planning to extend its territorial sea jurisdiction from 3 to 6 miles and its exclusive fishing zone to 12 miles in the near future.

A second reason for Argentine displeasure over Soviet fishing activities was the use of explosives by the Soviets to kill large quantities of fish. Argentine fishermen were so infuriated that they threatened to strike against the government for its apparent lack of concern and began to speak out in favor of a 200-mile limit.

A 200-MILE ZONE

The Soviet Union continued to fish off Argentina in 1967. In fact, Soviet fishing activities in the southwest Atlantic were more intense than during the previous year in spite of the issuance of a decree by Argentina extending its territorial sea and maritime jurisdiction to 200 miles in early January 1967. The decree required foreign vessels to obtain temporary permits to fish within 12-200 miles from shore and to pay inspection fees. In late January, the Soviet Union obtained permission to operate 40 fishing vessels within the 200-mile limit through 31 March and paid the required fees.

Although the Soviet Union generally complied with the initial temporary regulations, neither the Soviets nor the Argentines were satisfied with the situation. On 2 February, the Soviet Embassy in Buenos Aires issued a statement disputing Argentina's, or any other nation's, right to extend its territorial jurisdiction to 200 miles and called upon Argentina to reconsider its position. Argentine fishermen, for their part, kept up their protests over the presence of Soviet fishing vessels off the Argentine coast.

FISHING LAW ADOPTED

The Soviets, as well as other foreigners, continued to fish intensively throughout the year and as they did so, the Argentine government placed additional restrictions on foreign fishing off its coasts. On 24 September, fishing fees were increased for all foreign vessels operating within Argentine territorial waters. One month later, a fishing law, based on the January decree, was drawn up which established Argentine jurisdiction over the sea to 200 miles from straight baselines enclosing large bays. The resources in these waters were declared to be the property of the National Government which would henceforth grant concessions for their development.

In November 1967, Argentina announced its foreign fishing regulations which included license fees (US$10 per registered ton of fishing vessels every 120 days, double for fishery support vessels, processing factory vessels, and refrigerated fish carriers) and severe sanctions for violations of the 200-mile territorial sea. The fishing law became effective on 24 December, though enforcement was deferred until 1 April 1968. In December, about 70 Soviet vessels were still fishing off the Argentine coast. The total Soviet catch in the southwest Atlantic during 1967 was 677,700 t, more than a ninefold increase over the previous year. Most of the fish was harvested on the Patagonian Shelf off Argentina.

Early in 1968, talks on fishing rights began between Argentina and the Soviet Union, but broke down when the Soviets refused to pay license fees. When Argentina began to enforce its fishing law on 1 April, the Soviet fleet seemingly withdrew beyond the 200-mile limit.

SOVIET FISHING OFF ARGENTINA ENDS

Soviet vessels continued to fish in the area, however, and in June 1968 two Soviet trawlers were intercepted within

Argentina's 200-mile territorial sea. The vessels were fired upon and after one was hit amidships, both surrendered and were escorted into an Argentine port. After weeks of negotiations for the release of the vessels, the Soviet fleet finally left the Patagonian Shelf.

The Soviet catch in the southwest Atlantic declined precipitously and then remained at low levels in subsequent years (Table 2). The Soviet fishermen in the area made a brief recovery in 1970 when their fishing effort was intensified off the coasts of Uruguay and Brazil. This recovery was short-lived, however, because both Uruguay and Brazil soon extended their maritime jurisdictions to 200 miles.

At the end of 1972, only 14-16 foreign vessels were allowed to fish within Argentina's 200-mile limit. Fees had been increased to US$200 per deadweight ton; quantity (70,000 t) and species restrictions were also placed on foreign fishing operations. Foreign fishing was finally prohibited altogether in February 1973. If a foreign vessel were caught fishing illegally, it could be fined and have its catch confiscated.

Since 1973, Argentina and the Soviet Union have met on several occasions to discuss fisheries cooperation and aid programs. In 1974, for example, Soviet and Argentine fishery experts prepared a draft agreement on fisheries cooperation which included the following items: 1) Joint research, 2) Soviet training of Argentine fishery personnel, 3) construction of a fishing port, and 4) establishment of a joint fishing company.

In terms of increasing Soviet access to Argentine waters, however, discussions such as those in 1974 and others tied into more general trade negotiations produced few results. Soviet catches off Argentina continue to remain at low levels.

With respect to the latest seizures, the Soviet press has been relatively silent. A Tass news agency article in *Izvestiya* on 7 October gave a brief description of the incidents and protested the innocence of the Soviet vessel captains. The unnamed author of the article maintained that the Soviet vessels were outside Argentina's 200-mile limit when boarded and seized, but failed to mention that the Argentine navy had to give chase (under the "hot pursuit" doctrine) to effect the seizures. The article also intimated that the seizures of Soviet vessels were politically motivated[3].

FOREIGN FISHING AUTHORIZED

The Argentine Government has indicated increasing interest in developing the rich fishery resources of the Patagonian Shelf. Argentine fishermen, primarily from the northern port of Mar del Plata, have traditionally been hampered by limited domestic markets for fish. Argentine consumers prefer beef. A growing demand in Japan and Europe for cod-like species, such as hake, has focused considerable attention on the utilization of groundfish resources along Argentina's sparsely populated southern coast.

The Argentine Government granted the Federal Republic of Germany and Japanese companies permission (on 16 June 1977), to fish experimentally for hake off Argentina's coast south of lat. 40°S. The Soviet and Bulgarian vessels were seized within the zone where the West Germans and the Japanese have been authorized to fish. South Korean fishermen may also obtain an authorization to fish further south along the coast[4].

SEIZURES MAY INDICATE NEW POLICY

Press reports indicate that the recent seizures may represent an aggressive new foreign policy by the country's 18-month-old military junta aimed at asserting Argentine interests. The Navy Commander recently referred to Argentina's failure to live up to its potential and stated: "We have lost too much to be satisfied with ties, this time we are going to be the winners."

Press reports have also suggested that Argentine and South African officials have held discussions on security matters in the South Atlantic. The Argentine Foreign Minister, Vice Admiral Oscar Antonio Montes, has denied, however, that such discussions have taken place. The South Africans, unlike the Argentines, have allowed extensive foreign fishing off their coast and have only recently declared a 200-mile fishing zone which they implemented on 1 November 1977.

BOUNDARY DISPUTES

Two marine boundary disputes, one with the United Kingdom, the other with Chile, have increased Argentine sensitivities to any foreign intrusions on the Patagonian Shelf. Talks with the United Kingdom over the future of the Falkland or Malvinas Islands were held in Rome during July 1977, but reportedly failed to achieve a breakthrough. Further talks were held in December. The islands are a British Crown Colony, situated about 480 miles northeast of Cape Horn on the Patagonian Shelf, and their 3,000 residents, almost entirely of British ancestry, oppose transfer of sovereignty to Argentina. The Argentines have disputed United Kingdom sovereignty over the islands for more than a century and this issue has increasingly troubled relations with the British.

A second dispute with Chile has developed over the three small islands of Picton, Nueva, and Lennox in the Beagle Channel near Cape Horn. In May, the British government announced that an arbitration panel of International Court of Justice (ICJ) had awarded the three islands to Chile. The islands themselves reportedly have little intrinsic value, but may significantly affect marine boundaries and thus potential claims to the mineral, oil, and fishery resources of Antarctica. While Chile has accepted the decision, Argentina has not yet ratified the ICJ ruling. The two countries have held talks on this issue. (Source: IFR-77/269.)

[3] "One can only regret the fact that some forces in Argentina would like to use international fishing to undermine our trade, scientific, technical, and cultural links. Fishing is an absolutely peaceful business. That is why attempts to make it an object of aggravating relations between the Soviet Union and Argentina look so 'clumsy'." *Izvestiya,* 7 October 1977.

[4] A complete report on the Argentine authorization of foreign fishing can be obtained by requesting IFR-77/141R from NMFS Statistics and Market News Offices.

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